# PHYTOPATHOLOGY

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## ERRATA

Page 13, page heading "Gitman" should be "Gilman."
Page 19, sub-heading "Methods" should be in italics.
Page 20, sub-heading "Litmus agar" should be in italics.
Page 21, sub-heading "Sugar broths" should be in italics.
Page 21, sub-heading "Fermentation tubes" should be in italics
Page 21, sub-heading "Character of colonies" should be in italics.
Page 79, sub-heading "Experment" should be "Experiment."
Page 203, J. F. Faull should be J. H. Faull.
Page 205, Title of paper "$F^2$ " should be "$F_2$".
Page 236, Footnote reference should follow author's name
Page 240, line 14, "expreiment" should be "experiment."
Page 240, line 15, "passsed" should be "passed."
Page 243, page heading should be "Leonian: Valsa apple canker."
Page 243, line 10, omit dash after "$\mu$".
Page 249, page heading "Wof" should be "Wolf."
Page 259, page heading "Rumboid" should be "Rumbold."
Page 265, legend of figure 3, "Wacr" should be "Water.
Page 266, heading in table "Pycoida" should be "Pycnidia."
Page 266, heading in table, add "$\mu$" to "Mean size in.".
Page 266, plate IX, figures are reversed.
Page 271, add 1 to page number.
Page 271, table title add "S" to first word.
Page 271, footnote add "k" to last line, first word.
Pages 277 and 278, figures are transposed.
Page 291, last 10 lines, should be at top of page.
Page 337, title "Folliage" should be "Foliage."

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DR. F. KOLPIN RAVN

PHYTOPATHOLOGY

VOLUME XI NUMBER 1

JANUARY, 1921

# FREDERICK KOLPIN RAVN

H. H. WHETZEL AND H. B. HUMPHREY

WITH PORTRAIT. PLATE 1

The death of a great man at the close of a long and fruitful life touches us as does a passing cloud on a beautiful autumn day, but the sudden loss of a brilliant colleague in the prime of life comes like a bolt from the blue of the summer sky. Thus came the death of Kolpin Ravn on May 25 last, while on a visit in this country. But a few days before we had walked with him, talked with him, planned with him.

In the death of Kolpin Ravn plant pathology has suffered a great loss. Not only Denmark but America also will miss, with the passing years, his inspiring personality, his guiding vision, his productive genius. Not alone in physical stature, but also in mental ability and in personal charm he towered among his contemporaries, an inspiring teacher, a brilliant investigator, a rare leader, and a good friend.

Frederick Kolpin Ravn was born May 10, 1873, at Aalborg, Denmark, and died May 25, 1920, at East Orange, New Jersey. He received his early education at the Cathedral school in Aalborg, where he early showed natural inclinations toward a botanical career. In 1890 he went to the University of Copenhagen. Here, coming under the influence of the noted botanist Warming, he specialized in botany. His early botanical interests in the university were in ecology, especially the ecology of water plants. His first contribution to botanical science was an anatomico-ecological investigation on the floating ability of the seeds of certain hydrophytes. The thesis for his master's degree was on the organs of assimilation in the mistletoes. This interest in ecology continued throughout his life and strongly colored his later studies and investigations on the diseases of plants. This is especially noticeable in his work on the club-root of crucifers, where he pointed out for the first time the fundamental nature of the action of lime when applied to the soil for the control of this disease, showing that it was the response

of the pathogene to a basic condition of the soil rather than to some specific action of the lime as such.

Ravn became assistant to E. Rostrup in the botanical department of the Royal Agricultural College in Copenhagen in 1892. Under the influence of this great Danish phytopathologist he promptly turned his attention to the diseases of plants. His first interest in this field was with the diseases of trees but, influenced by Professor W. Johannsen, he soon turned to the diseases of agricultural crops, and particularly to their economic aspects. Thus it came that he undertook that extensive and intensive study of the Helminthosporium diseases of cereals which was to give him later an eminent position in cereal pathology. As a result of this investigation he was given his doctor's degree in 1900.

The following year he studied abroad in Germany, Austria, and Switzerland, working especially under Strasburger at Bonn. On his return from Germany he began his life work as associate with Rostrup in the phytopathological work in Denmark. The outstanding feature of his career from this time forward is the organization of the economic development of plant pathology in his native country. Carl Ferdinandsen, his successor, in his biography of Ravn[1] has most happily pictured those characters of the man which so eminently fitted him for the task.

"To solve the problems encountered here, Ravn was marvelously equipped. He possessed a clear, quick perception, permitting him to penetrate to the heart of the matter in question through all extraneous things, a sure scientific discretion mated with unusual practical ability, and enthusiasm for the subject in hand, which infected all with whom he worked, a quick well-poised manner which earned confidence and respect, and an equable, sunny disposition which carried him triumphant over all difficulties."

On the death of Professor Rostrup he was called to the chair of plant pathology in the Royal Agricultural College in Copenhagen, which position he filled until his death with a brilliancy and a record of attainments wholly worthy of the great master whom he succeeded.

The best evidence of his power as a teacher is the enthusiastic interest in plant pathology exhibited by the younger generation of students who came under his influence. It is, however, as the organizer of practical phytopathological work in Denmark that Ravn's ability is

[1] Nordisk Jordbrugsforsking. June, 1920. The writers are under deep obligations to Mrs. Ravn for the biographical data, especially for the translation of this biography of Ravn by his student and successor, Carl Ferdinandsen, which translation she personally prepared.

best exhibited. In this he has rendered signal service to his country and has set an example for emulation by pathologists in other lands. His leadership in this development is best shown in the positions of responsibility which came to him in this connection. From 1905 to 1907 he was Consulting Specialist in Plant Diseases to the Cooperative Agricultural Societies; from 1907 to 1918, Leader of the State Experimental Work in Plant Pathology and Leader of the Cooperative Agricultural Societies' Experimental Work in Plant Diseases; from 1907 to 1920, Consulting Specialist in Plant Diseases to the Department of Agriculture; from 1913 to 1920, Leader of the State Inspection Service for Contagious Plant Diseases; and from 1917 to 1920, Member of the Board of Supervisors of the State Seed-Testing Station. He was made a member of the State Board of Agriculture in 1920. It may well be said that phytopathological progress in Denmark during the past two decades is the work of his hands. Few of us who live longer than he will accomplish as much.

Although Ravn's interest in plant pathology was confined to no particular crop group, it is in the investigation of cereal diseases that he really won his place among pathologists. In his monograph on Helminthosporium[2] we find him at his best. This exceptional paper placed him at once in a position of authority on this important genus of disease-producing fungi, and made for him a permanent place among the leading plant pathologists of Europe and America. His other published works on cereal diseases are concerned almost entirely with problems of control, and in every case we find him making a direct contribution to our knowledge of crop sanitation and cereal disease prevention.

On invitation of the Office of Cereal Investigations, Bureau of Plant Industry, Ravn came to the United States in the spring of 1915 to give a series of lectures before the students and plant pathologists of several universities and colleges of agriculture. His itinerary took him into all of the important cereal crop states at a time of year when, from the standpoint of the pathologist, these crops are always most interesting. Wherever he went he made careful observations and notes on many diseases of cultivated plants and particularly those of cereals.

It was on the very eve of the development of something like a nationwide realization of the importance of cereal pathology to human economy that Ravn paid his second visit to this country. If we needed any prompting as to the necessity for widespread crop sanitation imposed upon us by the Great War, Ravn was here to make the helpful sugges-

[2] Nogle Helminthosporium-Arter og de af dem fremkaldte Sygdomme hos Byg og Havre. *In* Bot. Tids. **23**: 101–321, 26 figs., 2 colored plates. 1900.

tion and give impetus and inspiration to American cereal pathologists everywhere. He told us of the successful campaign of barberry eradication that had been waged in Denmark since 1903, and did not hesitate to recommend a similar campaign against stem rust of wheat and other cereals in America. Ravn expressed much confidence in the success that would ultimately follow such a campaign of barberry eradication. He admitted that stem rust would, in all probability, always be with us, but that the damage resulting from this rust would be greatly reduced through the removal and destruction of the barberry.

In May, 1915, while visiting some wheat fields near Sacaton, Arizona, Ravn discovered and recognized in this country for the first time what in Europe is an all too common rust of wheat, namely, stripe or yellow rust (*Puccinia glumarum* Erikss. and Henn.). From that time on throughout the journey through the states of California, Oregon, Washington, and Idaho, we found stripe rust at many points and on a wide range of gramineous hosts. Other cereal diseases with which we had some slight acquaintance were observed by him, particularly certain of those induced by unsanitary soil conditions. His live interest in and wide knowledge of ecology as applied to plant pathology enabled him to make many useful and practical suggestions relative to the control of such obscure diseases as those which have sometimes been referred to as due to "soil sickness."

To those of us whose privilege it was to accompany Ravn across the continent and through the Pacific and inter-mountain states there came that kind of inspiration and high resolve we experience only when we make contact with big-souled, high-minded men. When in his presence we felt instinctively his sincerity, his honesty, and his delightful humanity. An eager listener and keen observer, nothing of importance could easily escape him. Because of these gifts, he had at his easy command a fund of knowledge rarely possessed by men engaged in scientific pursuits. Everything worth while was of more than ordinary interest to him and consequently it is not to be wondered that he was a man of very unusual ability and renown.

Ravn was an international figure in his profession. He traveled widely both in England and on the Continent and had three times visited America; first in 1910, again in 1915, and finally in 1920. When last we talked with him, he spoke with confidence of another visit here five years hence.

The ties which bound Ravn to America were not only those of professional friendship and personal esteem, but also those arising from marital relations; his wife is an American woman. We like to believe that America was thus to him a second home land. He always seemed

to feel at home among us. Certain it is that we always felt at home with him.

No other European pathologist is so widely known and so highly esteemed among his American colleagues as Frederick Kolpin Ravn. He has rendered us professional services of great worth. Had he, however, brought to us nothing but the inspiration of his genial personality, we should still have been his debtor.[3]

[3] For complete bibliography see: Christensen, C. Den Danske botaniske Litteratur 1880–1911. 1913; and Bibliographies in Botanisk Tidsskrift.

# MEASURING CERTAIN VARIABLE FACTORS IN POTATO SEED TREATMENT EXPERIMENTS

I. E. Melhus and J. C. Gilman

With Five Figures in the Text

It is a well-known fact that the value of seed treatment is not constant. This is doubtless due to certain unknown variable factors. Unless these are measured, no set of data can be fully interpreted. The first of these variables is the presence of the living pathogenes on the tubers after they have been treated; second, the antiseptic action rather than disinfecting qualities of some of our fungicides used in surface disinfection of seed tubers, and third, the percentage of infection resulting from the presence of the pathogene in the soil. There are other factors that influence the results obtained in any set of seed treatment experiments, but the three cited above are probably the most important, and need to be measured in any well-planned series of field trials.

It has been quite generally assumed that when potatoes were treated with either formaldehyde or mercuric chloride that disinfection was quite complete. That such is not the case was clearly brought out in some of our seed treatment experiments in 1919. The seed was treated with various dilutions of formaldehyde and mercuric chloride at different temperatures and allowed to dry as in practice. Subsequently these tubers were examined in the laboratory before planting for the presence of living pathogenes i. e., *Actinomyces scabies* and *Rhizoctonia solani*.

A word of explanation of the technique utilized may serve to give a clearer understanding of the results obtained. In the case of common scab, isolations were made from the scab sori following treatment, using the method described by Shapovalov[1]. This consists of plating from the tissues just below the scab sorus. Two plates were made from each sorus and a like number from check tubers that received no treatment. These were held at favorable temperatures for the growth of the organism (22°C.) for three days and then counts were made of the number of colonies. In the case of *Rhizoctonia solani*, the sclerotia were picked off from the treated and untreated tubers and planted on potato agar plates. This organism grows rapidly at room temperature so that the

[1] Shapovalov, M. Effect of temperature on germination and growth of the common potato-scab organism. Jour. Agr. Res. **4:** 129–133. 1915.

living and dead sclerotia could usually be counted by the second or third day. The seed treatments used and the results obtained are recorded below.

THE EFFICIENCY OF SURFACE DISINFECTION ON POTATO TUBERS. ACTINOMYCES SCABIES.

The data from plates poured from scab sori which had been treated for various lengths of time, concentration of formaldehyde and temperatures are given in Table 1. Two facts are outstanding; first, that in only one of the treatments were all the organisms in the treated sori killed, and second, that in the untreated, all the sori did not contain viable organisms.

From the standpoint of toxicity of the fungicides, formaldehyde and mercuric chloride at the strengths used seem to be about equally efficient. The toxicity varied with the time of exposure, and the temperature.

The extent of disinfection is registered in terms of the number of colonies. Some idea of the thoroughness of the disinfection can be gained by comparing the figures in the columns headed, "number of colonies," under "treated" and "checks."

In the 7 modifications of the formaldehyde treatment the percent viable after treatment ranged from 3.6 to 0 per cent. These percentages will vary with any given set of isolations from treated and untreated tubers; therefore, the percentages cited above should be taken merely as indicators of the toxicity of any given treatment and not as an absolute expression of its value.

TABLE I

*Toxicity of Formaldehyde and Mercuric chloride to Actinomyces scabies*

| TREATED | | | | | | | CHECKS | | |
|---|---|---|---|---|---|---|---|---|---|
| Fungicide | Concentration | Temperature | Time Min. | Cover Min. | No. plates | No. colonies | No. plates | No. colonies | % viable after treat. |
| $CH_2O$ | 1–120 | 50° C. | 2½ | 15 | 30 | 18 | 30 | 494 | 3.6 |
| " | " | " | " | 1 hr. | 38 | 0 | 38 | 2851 | 0 |
| " | " | 5–6° C. | 2 hrs. | | 20 | 6 | 20 | 1789 | 0.3 |
| " | " | 10° C. | " | | 10 | 2 | 10 | 414 | 0.5 |
| " | " | 20° C. | " | | 10 | 1 | 10 | 769 | 0.1 |
| " | 1–240 | 5–6° C. | " | | 20 | 12 | 20 | 1398 | 0.8 |
| " | " | 20° C. | " | | 28 | 8 | 28 | 1640 | 0.5 |
| $HgCl_2$ | 1–1000 | 23–20° C. | 1½ hrs. | | 20 | 9 | 20 | 3071 | 0.3 |

Mercuric chloride of the standard formula gave 0.3 per cent viable after treatment. The data show clearly the fungicidal action and efficiency of formaldehyde and mercuric chloride. It is apparent that a great number of organisms are killed but not all. Considering the great number that is present in a sorus and the number of sori on a tuber it is clear that even on treated seed many viable organisms go into the ground. If then conditions are favorable for the multiplication of the same, the progeny of treated seed has ample opportunity to become infected. In other words, since surface disinfection is not absolute, the organism is transmitted into the ground on the seed and has an opportunity to multiply and infect the progeny.

The results obtained on the viability of the pathogenes after treatment in the laboratory were compared with the amount of diseased progeny found in the field for any given treatment. The tubers, after treatment, were cut to one or two "eyes" and placed in parallel rows two hundred sets to the row. Checks were placed at approximately every sixth row. The seed potatoes were of the early Ohio variety badly infected with common scab. Thirty-six different treatments were tried. In the fall the rows were dug and the progeny divided into clean and diseased progeny and weighed. The per cent of diseased progeny was calculated and these are the figures used for comparison with the laboratory data obtained previously.

In figure 1 the results secured in the various seed treatments on *Actinomyces scabies* in the field and in the laboratory in 1919 are compared graphically. The solid histographs represent the field data: the outlined graphs the laboratory data. The field data is given in per cent scab per row. The laboratory data in per cent of plates showing colonies in the treatment.

Examination shows that in eight of the eleven cases where comparison is made that the per cent of scab in the field is less than the per cent of plates showing colonies in the laboratory. The wide variation in percentage of common scab in the different treatments was doubtless due, in the cases where this percentage is excessive, to soil infestation. The exceptions to this condition are all the hot formaldehyde treatments of above 2 minute duration. In this group the laboratory data gave a lower percentage of scab on the plate cultures and a higher percentage in the field. Nevertheless, when the treatments are considered comparatively we find that the 1–120 treatment at 50°C for 1 minute showed a greater percentage of scab present in both field and laboratory than did the same treatment for 2½ or 5 minutes. The 2½ minute treatment with an additional covering of 1 hour gave identical percentages with the 5 minute, not covered,

treatment in both field and laboratory. These graphs show that there is sufficient correlation between the laboratory and field data to give the laboratory data a distinct value in forecasting what will happen in the field.

RHIZOCTONIA SOLANI

The response obtained in planting 900 sclerotia of Rhizoctonia on potato agar is shown in Table 2. Five hundred and seventy of these were taken from potatoes treated in seven different ways. In six of the trials recorded, formaldehyde of two different concentrations was used. The time of exposure varied from 2½ minutes to 2 hours and the temperature from 6–8 to 50° C. In the seventh trial mercuric chloride was used. The average viability in the seven trials was 96 per cent. Three hundred and thirty sclerotia that received no treatment were tested as to viability before the treatments were made on a particular lot of seed potatoes. In the treated lots, from zero to 10.5 per cent of the sclerotia were viable after the treatments. This confirms the findings made on *Actinomyces scabies* in that it shows that a certain percentage of the organisms on treated tubers escape the effect of the treatment and are carried into the soil on the seed. · Of course this is not a very large percentage, but with favorable conditions for their growth and subsequent development, a considerable percentage of infection may result.

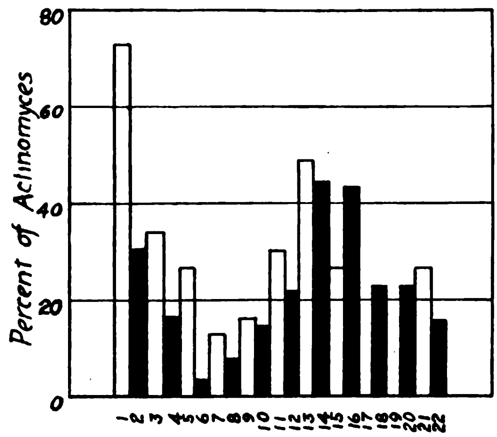


FIG. 1. COMPARISON OF FIELD AND LABORATORY DATA IN THE CONTROL OF COMMON SCAB.

| | | | | |
|---|---|---|---|---|
| 1 and 2—Infected, not treated. | | | | |
| 3 and 4—$CH_2O$ | 1–240 | 6–8° C. | 2 hrs. | |
| 5 and 6—$CH_2O$ | 1–120 | 6–8° C. | 2 hrs. | |
| 7 and 8—$CH_2O$ | 1–120 | 20° C. | 2 hrs. | |
| 9 and 10—$CH_2O$ | 1–120 | 48–50° C. | mom. | |
| 11 and 12—$CH_2O$ | 1–120 | 48–50° C. | mom. covered ½ hr. | |
| 13 and 14—$CH_2O$ | 1–120 | 48–50° C. | 1 min. | |
| 15 and 16—$CH_2O$ | 1–120 | 48–50° C. | 2½ min. | |
| 17 and 18—$CH_2O$ | 1–120 | 48–50° C. | 2½ min. covered 1 hr. | |
| 19 and 20—$CH_2O$ | 1–120 | 48–50° C. | 5 min. | |
| 21 and 22—$HgCl_2$ | 1–1000 | 20° C. | 2 hrs. | |

TABLE 2

*The toxic action of Formaldehyde and Mercuric Chloride under various conditions on the Sclerotia of Rhizoctonia*

| TREATMENT | | | | | TREATED SEED | | CHECKS | |
|---|---|---|---|---|---|---|---|---|
| | | | TIME | | SCLEROTIA | | SCLEROTIA | |
| Fungicide | Dilution | Temperature | Dipped | Covered | Planted | Per cent Grew | Planted | Per cent Grew |
| $CH_2O$ | 1–120 | 50° C. | 2½ min. | ¼ hr. | 50 | 2 | 30 | 90 |
| " | " | " | " | 1 hr. | 70 | 8.5 | 50 | 92 |
| " | " | 6–8° C. | 2 hrs. | | 50 | 4 | 50 | 100 |
| " | " | 20° C. | " | | 50 | 2 | 50 | 100 |
| " | 1–240 | 6–8° C. | " | | 50 | 0 | 50 | 92 |
| " | " | 26° C. | " | | 100 | 8 | 50 | 92 |
| $HgCl_2$ | 1–1000 | 20° C. | 1½ hrs. | | 200 | 10.5 | 50 | 98 |

In figure 2 a graphic comparison of the various seed treatments on *Rhizoctonia solani* in the laboratory and field is shown. The field data were obtained from seed of the early Ohio variety, handled as described under the common scab experiments. The solid histographs show the percentage of diseased progeny for each treatment. The outlined columns give the percent of viable sclerotia present after each treatment in the laboratory. Thirty-one cases are presented. In 16 cases the laboratory data showed a higher percentage of viable sclerotia than the percentage of infected progeny. In the other 15 cases the reverse was true. Nevertheless, the correlation between these two sets of data is very marked when the difference in method of measurement of the effectiveness of the treatment is considered. As a rule when the laboratory data showed a large percentage of viable sclerotia present after treatment, the field data gave a high percentage of infected tubers among the progeny from the seed treated in the same manner. The chief inconsistencies are found in columns 5 and 6, 7 and 8, 17 and 18, 33 and 34, 43 and 44, 47 and 48, 49 and 50, 57 and 58. In these eight cases we have brought out strikingly the difficulties of insufficient data due to too few trials. This point will be more fully discussed when we take up the question of soil infestation. Differences in soil infestation which would more than account for the slight inconsistencies found in this series manifested themselves when the same treatment was repeated several times in the field. On the whole the laboratory data was confirmed in the field and the number of viable organisms present after a treatment may be used as an indicator of the effectiveness of a treatment as a control measure.

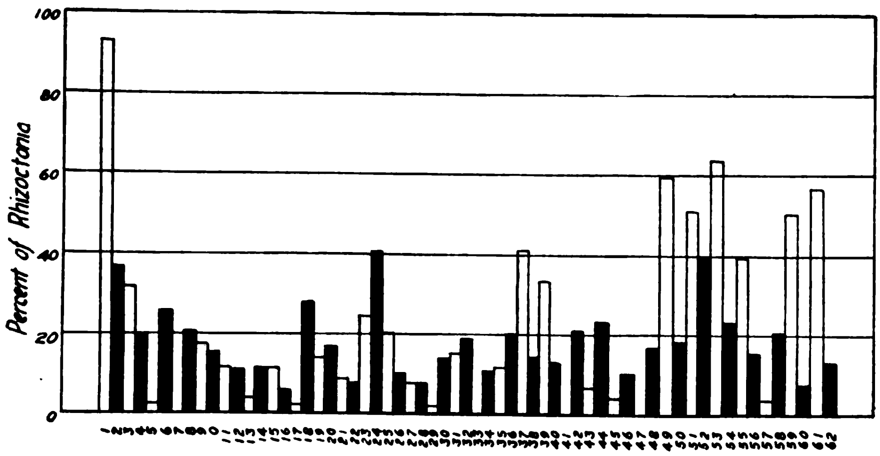


FIG. 2. COMPARISON OF FIELD AND LABORATORY DATA IN THE CONTROL OF BLACK SCURF

| | | | | | |
|---|---|---|---|---|---|
| 1 and 2—Infected, not treated. | | | | | |
| 3 and 4—$CH_2O$ | 1-240 | 6-8° C. | ½ hr. | | |
| 5 and 6—$CH_2O$ | 1-240 | 6-8° C. | ½ hr. | presoaked 24 hrs. | |
| 7 and 8—$CH_2O$ | 1-240 | 6-8° C. | 2 hrs. | | |
| 9 and 10—$CH_2O$ | 1-240 | 6-8° C. | 2 hrs. | presoaked 24 hrs. | |
| 11 and 12—$CH_2O$ | 1-120 | 20° C. | ½ hr. | | |
| 13 and 14—$CH_2O$ | 1-120 | 6-8° C. | 2 hrs. | | |
| 15 and 16—$CH_2O$ | 1-120 | 20° C. | ½ hr. | | |
| 17 and 18—$CH_2O$ | 1-120 | 20° C. | 2 hrs. | | |
| 19 and 20—$CH_2O$ | 1-120 | 50° C. | 1 min. | covered ½ hr. | |
| 21 and 22—$CH_2O$ | 1-120 | 50° C. | 1 min. | covered 1 hr. | |
| 23 and 24—$CH_2O$ | 1-120 | 50° C. | 2 min. | dried immediately. | |
| 25 and 26—$CH_2O$ | 1-120 | 50° C. | 2 min. | covered ½ hr. | |
| 27 and 28—$CH_2O$ | 1-120 | 50° C. | 2 min. | covered 1 hr. | |
| 29 and 30—$CH_2O$ | 1-120 | 50° C. | 2 min. | covered 1 hr. | presoaked 24 hrs. |
| 31 and 32—$CH_2O$ | 1-120 | 50° C. | 2 min. | covered 2 hrs. | |
| 33 and 34—$CH_2O$ | 1-120 | 50° C. | 2 min. | covered 5 hrs. | |
| 35 and 36—$CH_2O$ | 1-120 | 50° C. | 2 min. | covered 10 hrs. | |
| 37 and 38—$CH_2O$ | 1-120 | 50° C. | 5 min. | dried immediately. | |
| 39 and 40—$CH_2O$ | 1-120 | 55° C. | 1 min. | dried immediately. | |
| 41 and 42—$CH_2O$ | 1-120 | 55° C. | 1 min. | covered 1 hr. | |
| 43 and 44—$CH_2O$ | 1-60 | 50° C. | 2 min. | dried immediately. | |
| 45 and 46—$CH_2O$ | 1-60 | 50° C. | 2 min. | covered 1 hr. | |
| 47 and 48—$CH_2O$ | 1-60 | 50° C. | 2 min. | covered 5 hrs. | |
| 49 and 50—$HgCl_2$ | 1-1000 | 6-8° C. | ½ hr. | | |
| 51 and 52—$HgCl_2$ | 1-1000 | 6-8° C. | ½ hr. | presoaked 24 hrs. | |
| 53 and 54—$HgCl_2$ | 1-1000 | 6-8° C. | 1 hr. | | |
| 55 and 56—$HgCl_2$ | 1-1000 | 6-8° C. | 1½ hrs. | | |
| 57 and 58—$HgCl_2$ | 1-1000 | 6-8° C. | 1½ hrs. | presoaked 24 hrs. | |
| 59 and 60—$HgCl_2$ | 1-1000 | 6-8° C. | 2 hrs. | | |
| 61 and 62—$CuSO_4$ | 1-300 | 6-8° C. | 2 hrs. | | |

### ANTISEPTIC ACTION OF MERCURIC CHLORIDE

While making a comparative study of the effect of disinfectants on the sclerotia of Rhizoctonia on potato tubers some data were obtained which throw additional light on the confusion which now shades this problem. During the course of these studies it was found that mercuric chloride when used for short periods of time, acts to some extent as an antiseptic and not a disinfectant.

If in plating sclerotia from tubers treated with mercuric chloride the sclerotia after being removed from the potato with a sterile knife were turned over before being placed on the medium, a large percentage of the sclerotia grew. The surface of the sclerotium that was next to the epidermis was exposed to the air in the dish. This growth was not like that from untreated sclerotia but was a tuft of hyphae growing out of the center of the sclerotium and standing up perpendicular to the surface. (Fig. 3.) Microscopic examination showed it to be Rhizoctonia.

Table 3 shows the results of plantings made from sclerotia treated with mercuric chloride. It shows that many sclerotia are not killed in exposures less than two hours. It should be noted that Gloyer[3] found that mercuric chloride 1-1000 killed all of the sclerotia. This may have been due to the limited number of trials or some other combination of conditions not obvious from his data.

From these data it will be noted that the accepted time of exposure (90 minutes) does not kill all the sclerotia but that about 10 per cent of those plated grew. The gradual increase in toxicity with the increased time of exposure shows how slowly mercuric chloride penetrates. With a large sclerotium this factor becomes an important one.

The most plausible explanation of this phenomenon seems to be; that even after three washings in sterile water, sufficient mercuric chloride is left on the surface of sclerotia to inhibit the growth of the fungus. This substance did not penetrate the sclerotium, however, but was confined to the surface that was wetted at the time of the treatment. When the sclerotium was plated in the same relative position as it held on the tuber the fungicide remaining on the surface of the sclerotium inhibited its growth, but when it was turned over, the part of the sclerotium to which the fungicide had not penetrated was exposed to the moist atmosphere within the dish and growth readily took place. Additional evidence of the diffusion of the fungicide around the sclerotium

[3] Gloyer, W. O. The efficiency of formaldehyde in the treatment of seed potatoes for Rhizoctonia. N. Y. (Geneva) Agr. Exp. Sta. Bul. 370, pp. 417–431. 1913.

from tubers that had been treated with mercuric chloride was shown by behavior of contaminating organisms in the plates. These organisms (Penicillum, Rhizopus and Aspergillus spp. chiefly) would always leave a sterile zone immediately surrounding such sclerotia while on the check plates where sclerotia from untreated tubers were placed no such zone was observed. Sclerotia killed with formaldehyde solution did not show a sterile zone around them when plated. Further when 100 cc. of water used for the third washing was evaporated to 10 cc. a precipitate of mercury was obtained with stannous chloride as a reagent, Some of the water used in the third washing is transferred to the media with the sclerotium which would seem to account for the presence of mercuric chloride around each sclerotium on the plate.

FIG. 3. RHIZOCTONIA SCLEROTIUM FROM POTATO TUBERS TREATED WITH CORROSIVE SUBLIMATE 1–1000 FOR 1½ HOURS SHOWING GROWTH FROM ITS CENTER.

### MEASURING SOIL INFESTATION

Where the soil is infested with *Actinomyces scabies* and *Rhizoctonia solani* the value of a particular treatment is not clearly defined. Furthermore the infestation is never constant and the activity of these pathogenes is influenced by climatic factors which vary with the season. However, this variable must be measured in order to interpret a particular set of seed treatments. This has not been done in any set of potato seed treatments that have come to the authors' attention. The fact makes it seem justifiable to record the following results obtained in 1919 at Ames, Iowa, in studying the toxic action of various fungicides. Seed potatoes of the early Ohio variety badly infected with common scab and black scurf were used together with apparently clean seed from the

TABLE 3

*The Action of Mercuric Chloride on the Sclerotia of Rhizoctonia*

| TREATMENT | | TREATED SEED | | CHECKS | |
|---|---|---|---|---|---|
| | | SCLEROTIA | | SCLEROTIA | |
| Dilution | Time of exposure | Planted | Percent Grew | Planted | Percent Grew |
| 1–500 | 90 min. | 100 | 18 | 50 | 94 |
| 1–1000 | 30 " | 140 | 51 | 90 | 95 |
| " | 60 " | 90 | 43.3 | 90 | 95 |
| " | 90 " | 530 | 10.9 | 90 | 95.5 |
| " | 120 " | 50 | 0 | 50 | 100 |
| 1–2000 | 90 " | 150 | 26.6 | 50 | 100 |
| " | 120 " | 50 | 5.8 | 50 | 100 |

same source. The seed was cut to one or two "eyes" and planted 200 sets per row. The rows served as checks in a series of 36 different treatments and were distributed every sixth row. In the fall when the crop was harvested the percentage of common scab and black scurf was recorded by weight. Figure 4 shows 18 checks in three series, A. B. and C., where the Rhizoctonia infection was measured.

In the A series apparently clean seed was treated with mercuric chloride (1–1000) for 1½ hours. The apparently clean seed was obtained by selecting tubers from the bin on which no sclerotia were seen. It is not improbable however, that some few were overlooked due to irregularities of the surface and presence of inorganic matter. The clean seed was also used in B, but it received no treatment; in C untreated infected seed was used. The outlined histographs represent the percentage of black scurf by weight on the progeny in the fall. The shaded column is the mean of the six different checks. In the A series where apparently clean seed was used the amount of scurf varied from one to 18 percent with a mean of 6 per cent. This amount of infection was doubtless due to the scurf organisms present in the soil. The variation in soil infestation in the plot is shown in the variation in percentage of infected progeny. In the B series, the apparently clean untreated seed, we have a mean of 13 per cent which is the combined effect of the organisms carried on the seed and those already in the soil. It would seem that apparently clean seed is not free from scurf organisms and that seed treatment reduced the per cent of black scurf on apparently clean seed about 7 per cent. This is crediting 6 per cent of

the infection present on the progeny to organisms present in the soil as indicated in the A series.

In the C series which shows infected seed not treated we have a mean of 37 per cent infection in the six checks. This again is the combined infection resulting from the scurf organisms carried on the seed and those present in the soil.

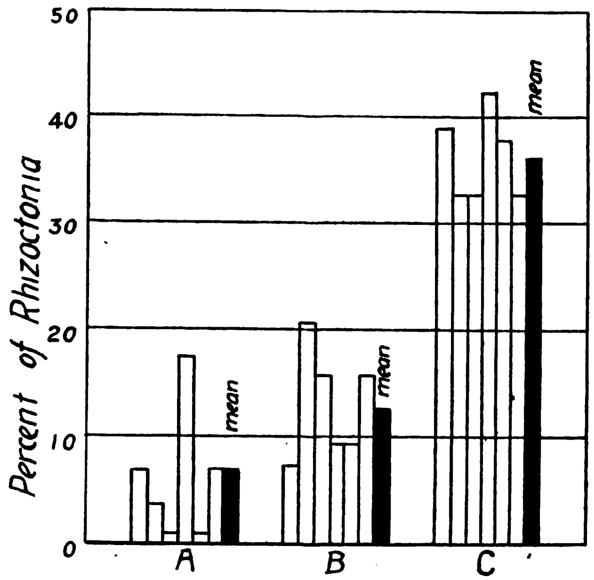


FIG. 4. MEASURING VARIATION IN SOIL INFESTATION BY RHIZOCTONIA SOLANI
*A*. Clean treated ($HgCl_2$ 1–1000 6–8° C. 1½ hrs.)
*B*. Clean seed not treated
*C*. Infected seed not treated

In figure 5 a similar series of checks used in the experiments on common scab are shown. In series A, the clean seed treated with mercuric chloride 1–1000 for 1½ hours showed a mean of 18 percent with a distribution of 10 to 29 per cent. Series B, consisting of clean seed not treated, showed a mean of 24 per cent with a distribution of 14 to 35 per cent infected progeny. In series C, the infected not treated group, the mean was 31 per cent with a distribution of 12 to 49 per cent. In addition to the same facts that have been pointed out for the black scurf series; that is, that the 18 per cent in series A shows the amount of soil infection; the difference between this figure and the 24 per cent in series B, 6 per cent, shows the amount of infection carried on the apparently clean seed, and the 31 per cent in series C shows the total

amount of infection present in the soil and that carried on infected seed; it should be noted that in certain instances, as for example, with the two rows in series A which show 23 and 29 per cent diseased progeny respectively two check rows are entirely inadequate as a measure of soil infestation. It is only by repeating the check rows at sufficiently close intervals that a true picture of the soil conditions can be attained. Variations which occur in all the series show that there are present in the soil, conditions which favor the development of the parasite in one case or inhibit it in another and in the same field. Such variations necessitate the use of frequent and varied checks in order that they may be correctly measured.

From this data where the check rows were repeated six times, the necessity of a large number of checks becomes obvious. Just how many should accompany any set of conditions is not so certain. It is well known that the reliability of any set of data is proportional to the square root of the number of repetitions. However, in the matter of checks the large number necessary for mathematical certainty cannot be used; therefore the question of how many to use remains. From the data given it is obvious upon inspection that one set of checks would

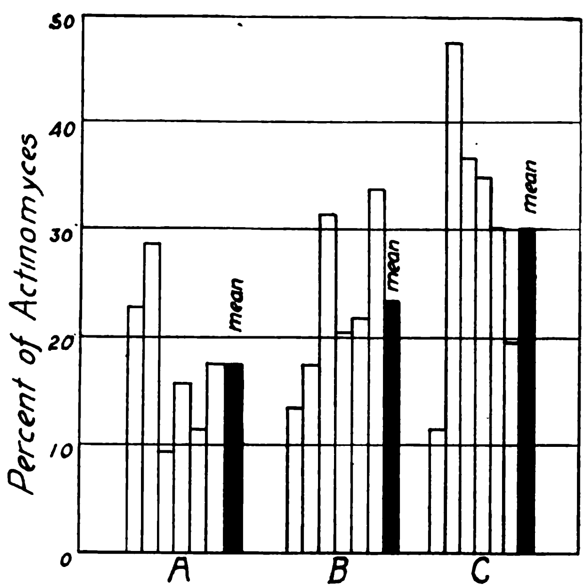


FIG. 5. MEASURING VARIATION IN SOIL INFESTATION BY ACTINOMYCES SCABIES
*A*. Clean seed treated ($HgCl_2$ 1–1000 6–8° C. 1½ hrs.)
*B*. Clean seed not treated
*C*. Infected seed not treated

be inadequate. For example in the common scab series the first two clean treated check rows gave a higher percentage of scabby progeny than four of the clean not treated and than two of the infected not treated seed. Again two of the clean not treated seed gave as much or more diseased progeny than did three of the infected not treated seed. Hence it may safely be concluded that in this case at least two checks are inadequate. Three sets of checks are little better, for with the combination of the three best infected not treated with the worst clean treated we find that the clean treated average 23.3 per cent of their progeny diseased while the infected not treated had but 21.3 per cent diseased. Such a case is not probable but is possible. A similar case is found in the Rhizoctonia series if the three best clean not treated be compared with the three worst clean treated, where the averages would be 8.3 and 11.3 per cent diseased respectively. Again with four repetitions of the checks the chances of wrong interpretation are lessened but are not entirely obviated. Where the presence of the organism often cannot be recognized as in the case of scab, the necessity of an increased number of checks over the case where the presence of the organism is easily observed, shows in these figures. This fact is brought out by comparison of figures 4 and 5. The greater differences between the means of the groups in figure 4 show that the dividing line of the tubers into clean and infected seed was much more efficient than in the scab series where the differences are less.

IOWA AGRICULTURAL EXPERIMENT STATION
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# FURTHER STUDIES ON BACTERIAL BLIGHT OF SOYBEAN

I. V. Shunk and F. A. Wolf

With One Figure in the Text

It will be recalled that two papers on bacterial blight have appeared during the past year, one from investigations conducted in Wisconsin by Miss Coerper (1) and the other in North Carolina by the junior writer (5). The disease in the case of the former of these accounts, is ascribed to a hitherto undescribed organism, *Bacterium glycineum,* and in the latter to an organism to which the name *Bacterium sojae* has been applied. Furthermore, the paper by Miss Coerper appeared in published form while the junior writer's manuscript was in press so that opportunity was not afforded for a critical comparative study of the two diseases and of the causal organisms. The foot-note (l. c. p. 120) accompanying this account was prepared by comparison with the published descriptive report, as has been indicated. Through the courtesy and kindness of Miss Coerper and of Dr. L. R. Jones, specimens and cultures have subsequently been received and it is, therefore, the present purpose to record the results of these comparative studies in order to clarify the problem of the identity of these soybean bacterial blight diseases.

## DIFFERENCE IN APPEARANCE OF THE DISEASES

Comparison of type specimens of diseased leaves shows that no differences are present which are sufficiently distinctive to make it possible to separate the two in the field. As previously indicated, however, minor differences, as in the color of the diseased areas and of the dried bacterial exudate, are apparent which no doubt vary dependent upon weather conditions and the stage of development of the disease.

Even though the disease in North Carolina has been quite prevalent during the present season, it appears to be confined to the leaves and has not been observed also on stems and pods as is the case in Wisconsin. It is doubtful if any means of identification save isolation of the causal organism can be relied upon. Isolations made during the present season from leaves collected in the vicinity of Raleigh, Oxford and Edenton, N. C., agree with those of previous seasons. Opportunity has not been afforded, therefore, to observe under field conditions, the

two leafspot diseases, which as indicated by the cultural studies to follow, must occur in Wisconsin.

### ORIGIN OF CULTURES

Five strains of soybean blight, four from Wisconsin and one from North Carolina, have been employed in the cultural studies. Data on those from Wisconsin can best be presented by quoting rather fully Miss Coerper's notes of explanation which accompanied the cultures.

No. 268. Isolated August 29, 1917. Naturally infected leaves were placed in damp chamber over night. Drops of bacterial exudate developed and streaks on potato agar slants were made by direct transfer. One of these isolations proved pathogenic when atomized on soy-bean leaves. Pathogenicity proved a number of times. Type strain. Browns peptone media. Employed in all cultural and inoculation work in soybean blight studies.

No. 269. Isolated August 31, 1918. Young leaf lesions were placed in 95 percent alcohol for an instant, then for one minute in 1–1000 solution of bichlorid of mercury and washed through six sterile water blanks. Dilution plates on potato agar were made from macerated lesions. Pathogenicity proved from inoculations in the field in 1918 and in the greenhouse during the winter of 1918–1919. Browns peptone media.

No. 270. Isolated January 17, 1919, from naturally infected leaf collected in the greenhouse. Surface sterilization was effected as in the case of No. 269 and dilution plates made. Does not brown peptone media. Pathogenicity proven by inoculation of plants in the greenhouse.

No. 211. This is the first strain isolated in the study of the disease, and was the strain used in all cultural and much of the inoculation work in comparison with the type strain No. 268. Isolated September 25, 1915. Does not brown peptone media.

The strain from North Carolina, herein designated No. 19, was isolated June 12, 1919, agrees culturally with a strain isolated during July of the previous year, has several times been proven to be pathogenic and is the type strain of *Bacterium sojae*.

### CULTURAL STUDIES

Method: Since it was early found to be impossible to verify the reaction of the strains toward carbohydrates by use of media prepared according to methods which have previously been employed, other methods, which included a more accurate adjustment of initial reaction and a more careful preparation of sugars, were adopted. These methods take advantage of recent refinements in methods of adjusting the reaction of culture media colorimetrically and electrometrically to supplant the inaccurate and illogical titration method which employed phenolphthalein as an indicator. They also take into account the well known fact that not only acid or alkali but also heat, can hydrolyze sugars and therefore interfere with the proper preparation of sugar media.

As is indicated in the preparation of Krumweide's brilliant green agar, sugars in distilled water and therefore apart from the influence of a complex solvent like culture media with its acid or alkali content, can be sterilized without appreciable hydrolysis and the sterile sugar can then be added to sterile media using aseptic precautions to prevent the necessity of subsequent sterilization. Accordingly, stock 20 per cent sugar solutions in distilled water were sterilized in the autoclave at 10 pounds for 10 minutes. Stock nutrient agar and bouillon were made as usual, were adjusted to the desired hydrogen ion concentration by comparison with the buffer color standards, were flasked and sterilized in 95 cc. quantities and then set aside until cool. When 5 cc. of the sugar solution was added to such quantities of media, using aseptic precautions, it contained 1 per cent of the sugar to be investigated. In the case of agar, which had an initial hydrogen ion concentration of pH = 7.0–7.2, the sugar was added to cooled but not yet solid media. It was then poured before the agar had set, into sterile test tubes, and was incubated for 48 hours to determine its freedom from contamination.

In making solid indicator media, sterile litmus solutions were prepared and the litmus was added in the same manner as the sugars. After growth had proceeded for a given time, in bouillon cultures containing sugars, which were used to check the results with solid indicator media, tests for acid were made by adding brom cresol purple or phenol red to the cultures and comparing them directly with the standards and with the uninoculated tubes. This last precaution seems to be of significance in the light of findings by Grace and Highberger (3) on variation in uninoculated media.

Litmus agar. Litmus agar in triplicate sets for each strain and for each of the sugars was used as indicator media. Each series included dextrose, saccharose, lactose, maltose and glycerine. Furthermore, each series was inoculated from the same stock culture and all cultures were incubated at 28 degrees C with the resultant reaction indicated by the litmus. No differences in strains were apparent on dextrose since the blue had practically disappeared from all tubes by the seventh day and they were reddened throughout. A slight reddening began on all strains on saccharose after three days and the upper part of the stab was definitely reddened by the seventh day. On each of lactose, maltose, and glycerine, Nos. 268 and 269 were able to bring about a slight change which was first apparent after about a week and the upper portions of the tubes became with age, a reddish brown, whereas, Nos. 211, 270 and 19 produced no acid from these sugars.

Sugar broths. In order to check the changes in reaction in solid media, the several carbon compounds were employed in 2 per cent peptone solutions. The media which had been adjusted to pH = 7.2 were inoculated and the changes after seven days were determined by comparison with buffer color standards. These data in terms of pH concentration are presented in the following tabulation:

*Reaction to sugars in peptone broth by soybean blight organisms*

| STRAIN | DEXTROSE | SACCHAROSE | MALTOSE | LACTOSE | GLYCERINE |
|---|---|---|---|---|---|
| 268 | 5.4 | 6.2 | 6.7 | 6.5 | 6.2 |
| 269 | 5.4 | 6.4 | 6.4 | 6.4 | 6.4 |
| 19 | 6.6 | 7.0 | 7.4 | 7.5 | 7.6 |
| 211 | 6.4 | 6.6 | 7.6 | 7.4 | 7.6 |
| 270 | 6.3 | 6.4 | 7.6 | 7.6 | 7.6 |

It will be noted that the results are in general accord with those on indicator media in that Nos. 268 and 269 are able to form acid from each of the sugars whereas Nos. 211, 270 and 19 form acid from dextrose and saccharose alone.

Fermentation tubes: Sterile fermentation tubes were filled under aseptic conditions with sugar broths. The dissolved oxygen gas was not driven off but it is not apparent that such a procedure is of value since it remains to be proven that heated broths do not again take up oxygen on cooling. The several strains have given similar results with heated and unheated tubed broths. No turbidity developed in the closed arm in seven-day old cultures thus indicating that the organisms are strictly aerobic. Other organisms may of course, react differently but the dispelling of dissolved oxygen is apparently a factor of less importance than the agitation given fermentation tubes in handling them during examination. Slight agitation may cause apparent growth in the closed arm in the case of all strains so that it becomes easily possible to misinterpret the oxygen relation through the use of fermentation tubes.

Character of colonies: It was only by increasing the percentage of agar above that which the writer was accustomed to use that it was possible to duplicate the appearance of colonies with respect to margin, contour and surface markings shown in Plate XV of Miss Coerper's paper. While it has long been known that the density and viscosity of media exert a profound influence on the character of the colonies (2), the importance of these factors has been largely overlooked in studies

involving the cultural characters of bacteria. In the case of the soybean organisms, the differences in the character of the margins in 1, 2, and 3 per cent nutrient agars which were alike in all other respects are shown in figure 1. It will be seen that the margin of the colony becomes more uneven as the density and viscosity increases. Size, elevation and surface markings are also profoundly modified.

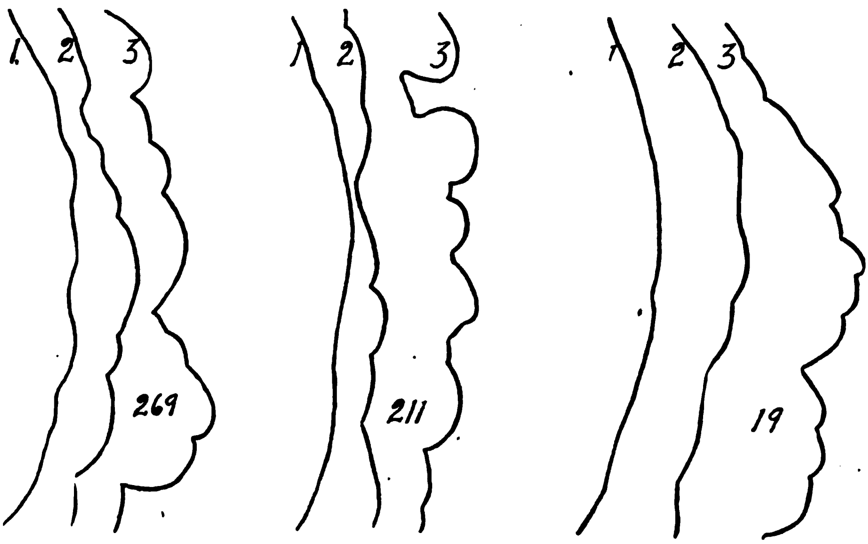


FIG. 1. VARIATION IN THE MARGIN OF COLONIES OF NOS. 269, 211 AND 19 WHEN GROWN ON 1, 2, AND 3 PER CENT NUTRIENT AGAR, AS SEEN UNDER THE HIGH POWER.

## DISCUSSION

By avoiding the heating of media after the addition of the sugar, one prevents the reaction between the amino groups and the sugar with the resultant production of acidity as occurs during sterilization. Since these strains form acid weakly, their reactions are not evident with media whose initial reaction, as determined by titration with phenolphthalein, is approximately pH = 8.5. When, however, the initial reaction closely approximates absolute neutrality, as determined colorimetrically, small increases in acidity consequent on growth are detectable. This is shown particularly in the case of No. 19, which with litmus agar adjusted to pH = 8.0–8.5 gives no evidence of its ability to form acid with saccharose. A similar condition has been reported by Jones (4) for a strain of Pneumococcus which when inoculated into a medium whose initial reaction was pH 7.0 grew poorly and developed a final concentration of only pH 6.2 whereas in a medium whose initial

reaction was pH 7.6 growth was abundant and a concentration of pH 5.4 was developed.

It has been possible to verify previously published accounts of the morphology and cultural characters of the soybean bacterial blight organisms in all respects except in the reaction toward the several sugars. Nos. 268 and 269, which in Miss Coerper's discussion on variations of strains (1 l. c. p. 189) are called Strain A, are regarded as identical and are the type of *Bacterium glycineum*. They have the same reaction toward dextrose, saccharose, lactose, maltose and glycerine, from the first two of which they form acid rather strongly, but from the others, in small amounts and slowly. They furthermore, consistently cause a browning of the media. Nos. 211 and 270 which are called Strain E are like No. 19, the type of *B. sojae*. They are able to form acid from dextrose and saccharose alone and agree in being non-pigment forming.

## SUMMARY

A comparison has been made of bacterial blight of soybean as described from Wisconsin and from North Carolina. The diseases differ somewhat in appearance but these differences are of minor importance and it is doubtful if one could differentiate them with certainty in the field. By the use of certain easily operable refinements which consist essentially in adjustment of initial reaction to neutrality and in reducing the hydrolyzation of sugars to negligible quantities, it is determined that the several strains of bacteria pathogenic to soybeans represent two distinct species, *Bacterium glycineum* and *B. sojae*. They differ principally in that the former produces brown pigment with certain media and forms acid from dextrose, saccharose, lactose, maltose and glycerine, whereas the latter is non-pigment forming and forms acid from the first two of these sugars only. Both organisms have been isolated in Wisconsin and proven to be pathogenic and *B. sojae* alone has been found to be associated with soybean blight in North Carolina.

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N. C. AGRICULTURAL EXPERIMENT STATION

## STOCKTON MOSBY McMURRAN

JOHN W. ROBERTS

WITH ONE FIGURE (PORTRAIT) IN THE TEXT

Stockton Mosby McMurran, Pathologist in Charge of Investigations in Nut Diseases, U. S. Department of Agriculture, was born at St. Paul, Minnesota, March 8, 1887, and died at Thomasville, Georgia, September 5, 1920. He was graduated from the Virginia Polytechnic Institute in

S. M. McMURRAN

1909 and received the degree of A. M. from Washington University in 1911.

McMurran had been a member of the Office of Fruit Disease Investigations, Bureau of Plant Industry, for eight years. Previous to that time he had been connected with the Department of Plant Pathology

in the Virginia Agricultural Experiment Station, New York (Geneva) Experiment Station, and Washington University (St. Louis Botanical Garden).

His first important piece of work was an investigation of the Anthracnose of the Mango in Florida, the results of which were published in bulletin form. He was then placed in charge of Nut Disease Investigations, a position which he held until his death. Some of his investigations of pecan rosette have been published under the title "Pecan Rosette in Relation to Soil Deficiencies," and constitute a noteworthy contribution to the subject. "Wood Rot of Pecans" and "Walnut Blight in the Eastern United States" are publications resulting from investigations urged upon him by nut-growers.

McMurran was possessed of a keen sense of humor and a certain buoyancy of spirit, which made him a delightful and much sought after companion. He was also possessed of a quick, active mind, whose brilliancy quickly impressed itself upon all with whom he came in contact. At the time of his death, McMurran was just beginning to solve many of the more vexing problems in Pecan diseases and his death is a distinct loss both to nut growers and to the science of Plant Pathology.

FRUIT DISEASE INVESTIGATIONS
BUREAU OF PLANT INDUSTRY

## PHYTOPATHOLOGICAL NOTES

*Witches'-brooms of Pinus maritima.* Witches'-brooms are often produced from a local hypertrophy of lateral shoots on *Pinus maritima* in southwestern France. Sections from a hypertrophied main shoot or from the smaller branches in the brooms show that the cambial cells are generally infected by bacteria imbedded in brown zoogloeae, which extend from one cell to the next through the bordered pits. The bacteria are best demonstrated in sections cleared in chloral phenol. They stain black with iron haematoxylin and blue with the polychrome-blue-tannin-orange method.

The nucleus and cytoplasm of the infected host cells may disappear. Occasionally the cell wall may break open, perhaps through the decomposition of the pectic substances, and the zoogloeae then push through the opening. The reactions of the host tissues are quite different from those in bacterial cankers. No giant cells, which are conspicuous in cankers, are observed in the witches'-brooms.[1]

The infection results chiefly in the differentiation of a number of cambial areas into shoot initials. As a result, an excessive number of lateral buds are formed, and these develop into shoots. In addition, the buds terminating the needle-bearing shoots, which are normally abortive, develop into branches.

Inoculations from diseased cambium to nutrient agar result in the formation of colonies of motile bacteria which appear macroscopically as brown spots in cultures three days old. The bacteria from the cultures measure $0.75\mu \times 3\text{–}5\mu$. They stain readily by the Ziehl-Nielsen process.

Bacteria from cultures ten days old were inoculated into buds of *Pinus maritima*. These inoculations resulted in the death of the buds, the tissues swarming with bacteria, but no witches'-brooms were formed. The infection experiments appear to prove the parasitism of the organism, but still leave it uncertain whether they cause the broom formation.

JEAN DUFRENOY

SERVICE DU EPIPHYTES
FRANCE.

[1] Dufrenoy, Jean. Pine-needles, their significance and history. Bot. Gaz., v. 66, p. 439–454, Nov. 1918.

*The relation of mosaic disease to pickling of cucumbers.* Snow's Perfection cucumbers were grown during the summer of 1920 at Arlington Farm, Virginia, for pickling purposes. The cucumber fruits showed the mosaic disease late in the season by pale blotches and rough warty areas. Incipient cases of earlier origin were doubtless overlooked. Fresh cucumbers affected by mosaic disease had a bitter taste and the texture was tough. When cucumbers are subjected to the pickling process, certain physical changes are observed. A fresh cucumber shows tissues with extensive intercellular spaces filled with air. A section of cucumber submerged in brine appears white on account of these spaces. During the pickling process this air is gradually eliminated, so that, when the fermentation is complete, the white spaces have disappeared with replacement of the air by acid brine. When the dill pickles made in the summer of 1920 were sufficiently cured, they were examined.[1] Jars 2–23, which were put up from cucumbers gathered before mosaic disease was apparent in the plot, showed practically no troubles except such as could be explained by other agencies than mosaic disease. There was, however, at least one pickle affected with mosaic disease, this being in the last jar, No. 23.[2] Beginning with the jar 24, the cucumbers were not sorted as carefully as in previous work and mosaic disease was marked. On examination of the subsequent eight jars of dill method pickles, the extreme effects of pickling mosaic cucumbers were noticed. Some cucumbers with mosaic infection have white areas with a tough, woody texture, which do not clear up during the pickling process. Other affected cucumbers become spongy or soft or slushy pickles. The pickle may be spongy only in the center, or the entire structure within the epidermis apparently may be broken down into its integral cellular parts. None of these bad pickles present disagreeable odors or putrefaction.

These preliminary results demonstrate the necessity of careful comparison of pickles made from cucumbers apparently free from mosaic, but from stock known to be affected, with pickles from stock known to be unaffected. In this way it will be possible to determine what relation may exist between this disease in the field and losses in the pickle vat, even when the stock has been sorted carefully while fresh. The

[1] These experiments were conducted in consultation with Dr. Charles Thom, of the Bureau of Chemistry.

[2] Identification of mosaic disease by Mr. W. W. Gilbert, of Bureau of Plant Industry; pickling would undoubtedly disguise many cases of incipient mosaic.

work presented indicates that cucumbers visibly affected with mosaic will not cure properly in the pickling vat.

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*Foot rot of tomato.* Pethybridge and Lafferty (Sci. Proc. Roy. Dublin Soc. **15**: 487–505. 1919) have applied the name foot rot to a disease of tomatoes caused by *Phytophthora cryptogea.* In view of this usage, Rosenbaum's proposal (Phytopathology **10**: 415–422. 1920) to apply the same name to a tomato disease caused by *Macrosporium solani* seems unfortunate if not untenable. Use of the generic names of the causal organisms as descriptive adjectives would still allow the use of a descriptive common name and such usage has certain additional advantages. If this suggestion is followed the two diseases of tomato would bear the common name Phytophthora foot root and Macrosporium foot rot.—*D. Reddick.*

*New abstract journal. Zentralblatt für die gesamte Landwirtschaft mit Einschluss der Forst- und Teichwirtschaft, der Tier-Pathologie und Medizin* is a new abstract journal issued by Prof. Dr. Richard von der Heide, of the Agricultural College in Berlin, and Robert Lewin, Berlin No 43, Prenzlauer Berg 8. It is published by Gebrüder Borntraeger, Berlin W 35, at the subscription price of 75 marks for a volume of about 500 pages. In the list of abstractors appear the names of the following pathologists: Lindfors (Experimentalfältet), Losch (Hohenheim), Molz (Halle a. S.), Schoevers (Wageningen), Zimmermann (Rostock). In the four numbers that have been seen, several central European journals are reviewed the names of which will prove decidedly unfamiliar to most American workers. Some of these journals really are new, the first volume having appeared within recent years; others bear high volume numbers but the names do not seem to have appeared frequently, if at all, in abstracting or reviewing journals. How many of these represent merely changes in spelling made possible by recent political changes has not been determined.—*D. Reddick.*

*Compilation of list of new fungi.* The British Mycological Society intends to publish the original diagnoses of the genera of fungi which have appeared since the last volume (XXII) of Saccardo's Sylloge, and to keep the list up to date by annual installments. Dr. J. Ramsbottom, general secretary of the Society, British Museum (Natural History), Cromwell Road, London, S. W. 7, has undertaken to compile this list,

and would welcome separates in which new genera have been described, or assistance in any way. It is believed that the list will be valuable to all interested in mycological studies.—*W. A. Orton.*

*Personals.* Mr. M. A. Carleton, formerly in charge of the Office of Cereal Investigations, United States Department of Agriculture, and recently plant pathologist for the United States Grain Corporation, is now employed as plant pathologist for the United Fruit Company, with headquarters at Bocas del Toro, Panama.

Dr. O. F. Burger, formerly pathologist at the California Agricultural Experiment Station, Riverside, and recently engaged in the investigation of fruit and truck crop diseases in the U. S. Bureau of Plant Industry, has become head pathologist at the Florida Agricultural Experiment Station, Gainesville. He will give special attention to the study of transportation diseases of truck and citrus crops.

Mr. R. W. Goss, formerly assistant pathologist in cereal disease investigations, Bureau of Plant Industry, with headquarters at Madison, Wis., has become assistant plant pathologist at the Nebraska Agricultural Experiment Station, where he will take up the study of the potato Fusarium problems of that region.

Dr. R. A. Jehle, formerly extension plant pathologist for the North Carolina State College of Agriculture, has accepted a similar position with the College of Agriculture of the University of Maryland, succeeding Prof. C. E. Temple, who has become professor of plant pathology in the University of Maryland.

Mr. E. J. Wortley, formerly Director of Agriculture for Bermuda, has accepted a similar position for the Nyasaland Protectorate and is located at Zomba.

## *ABSTRACTS OF PAPERS PRESENTED AT THE TWELFTH ANNUAL MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY, CHICAGO, DECEMBER 28 TO 31, 1920.*

*Experiments with Stewart's disease on dent, flint and sweet corn.* CHAS. H. REDDY.

In connection with investigations on the bacterial diseases of corn carried on by the Office of Cereal Investigations, United States Department of Agriculture, two series of experiments consisting of two hundred plants each were conducted under greenhouse conditions at Madison, Wisconsin, during the winter of 1919–20, to test the relative susceptibility of one variety each of dent, flint and sweet corn to bacteria of the *Aplanobacter stewarti* type isolated from natural infections of dent, flint and sweet corn occurring in 1919 in the vicinity of Bloomington, Illinois. The same soil was used in both experiments. Thus the second experiment also served as a test on natural soil infection under greenhouse conditions where corn is grown in the soil immediately upon the removal of a diseased crop. Cross inoculations on the three kinds of corn were made with water suspensions of cultures from dent, flint, and sweet corn respectively, by hypodermic injections near the bases of corn plants. Ninety per cent of the plants inoculated were infected as determined macroscopically, and by isolations from points several inches above places of inoculation. Results indicate that the organism isolated from each, dent, flint and sweet corn is about equally pathogenic on all of the hosts under experimentation. Neither dent, flint, nor sweet corn showed marked resistance. However, on basis of intensity of infection, flint corn seemed to be the most susceptible and dent the least susceptible. There was not a single case of natural infection resulting from growing corn in soil which, immediately preceding, had produced a crop artificially infected.

*Studies on corn rust.* G. F. WEBER.

In connection with studies on the urediniospores of *Puccinia sorghi* Schw. carried on at the University of Wisconsin, 1919–20, data were accumulated particularly on: (1) overwintering, (2) relation of temperature to germination, (3) mode of host penetration, and (4) relative susceptibility of corn species and varieties.

Beginning October 1, urediniospores were collected every two weeks from infected corn leaves placed at different stations out of doors, and their viability tested. Through October one hundred per cent germination was obtained. Through November the germination percentage diminished gradually, and at the end of December germination ceased entirely. Studies on urediniospore germination conducted in incubators at different temperatures indicated 4°, 17°, and 32° C. to be the minimum, optimum and maximum temperatures respectively. Sectioned material fixed at twenty-four-hour intervals after inoculation indicated that germ-tube penetration of host occurred through stomata only, either with or without appressoria. Greenhouse cross inoculations on seven species of corn with spores from each species used separately indicated no specialization, each species being similarly attacked by spores from any source.

The seven species of corn varied somewhat in susceptibility progressively in the following order:

(1) *Zea everta* (pop)
(2) *Z. tunicata* (pod)
(3) *Z. ramosa*
(4) *Z. dentata* (dent)
(5) *Z. amylacea* (flour)
(6) *Z. indurata* (flint)
(7) *Z. saccharata* (sweet)

Six varieties of dent corn tested showed but slight variations as to susceptibility.

*Ecologic and physiologic notes on corn smut, Ustilago zeae.* L. E. MELCHERS.

It has been found that cultures of *Ustilago zeae* seem to differ in their power to produce infection. Occasionally a culture will be isolated that proves to be "very infectious," when used for artificial inoculation. Frequently cultures are isolated that cause a rather small percentage of infected plants when used in inoculation experiments. Also, it is being found that selections and crosses of corn showing resistance to smut in one locality or state are much more susceptible in other sections. There seems to be an indication that the nature of the corn plant, and the change of environmental conditions with its effect on the host, are not solely responsible for such striking differences in smut resistance or susceptibility. Work under way indicates that there are physiologic differences in the corn-smut organism, that may be of considerable importance in breeding corn for resistance to it. (Coöperative investigation by the Kansas Agricultural Experiment Station and the U. S. Office of Cereal Investigations.)

*Significant points in the life history of the Philippine maize mildew.* W. H. WESTON, JR.

Several Sclerosporas of corn, although not yet introduced into our own country, are spreading so widely and proving so disastrously destructive in the Orient that they now constitute a serious menace to our own crop. A study of the one which occurs in the Philippines has brought out several points, which are of interest to American phytopathologists. The conidia of this Sclerospora are produced only at night when the infected leaves are covered with a layer of dew or other moisture. Production of conidia in vast numbers from infected but still vigorous plants may continue night after night for over two months. Consequently, one diseased plant may infect the whole countryside. Conidia may be produced on corn, teosinte, sorghum, sugar cane, *Saccharum spontaneum*, and *Miscanthus japonicus*. Oogonia are found only on the last three species. Local distribution is accomplished through the dispersal of conidia by night breezes of varying strength. Since the conidia can not survive drying, spread to distant countries must take place through the transportation of oogonia either in soil or adherent to seeds and other plant parts, or through the transportation of infected cuttings as of sugar cane. These and other points bear on the problem of pathological procedure against foreign diseases.

*A bacterial root and stalk rot of field corn.* H. R. ROSEN.

A disease of field corn has been observed in widely scattered localities in Arkansas which at times renders useless or kills twenty to thirty per cent of the stalks. The disease is characterized by a rotting accompanied by a light or dark-brown discoloration of the nodes, usually the lower ones. Under favorable conditions, such as a high humidity and temperature, the rot extends through the entire thickness of the stem in a few days time; the tissue attacked collapses and disintegrates, and the stalk topples over. Roots, leaf-sheaths, leaf-blades, and husks are also attacked. Eighteen varieties of field corn and one variety of sweet corn are known to be subject to the disease. Bacteria have been observed in constant association with diseased tissue. Numerous

isolations reveal a white, motile, rapidly growing, rod-shaped bacterium. Pure cultures of tbe organism, applied as a spray in water suspensions or as needle smears, produce infections on roots, stems and leaves similar to the natural ones. In the infections thus produced the organism has been found within the diseased tissue and has been reisolated.

*A Fusarium wilt of corn in Iowa in 1920.* J. C. GILMAN.

In Iowa a disease of corn was observed in the field when the plants were about six inches high. At this time, certain plants showed marked tip-burn of the leaves, especially the lower pair. This tip-burn was accompanied at times by wilting of the plant. Certain of these plants were pulled and upon cutting showed a brown discoloration of the vascular system at the base of the stalk. Isolations showed the presence of a Fusarium in 93 per cent of the cases. Other hills containing typically diseased plants were marked and at harvest time 85.6 per cent of these marked hills contained either barren or dwarf plants; 68.1 per cent showed barren-dwarfs present. The mortality in these marked hills was 5.8 per cent as compared with 2.1 per cent in the entire field. These two facts indicate that a Fusarium wilt was causing considerable damage to the crop. This disease corresponds markedly with the early stages of root-rot as described by Hoffer and Holbert but differs in the following respects: first, the hills which showed the wilt did not exhibit broken, leaning or down stalks at harvest time, but were most erect in the field. Down and leaning stalks throughout Iowa showed rotten roots within a short time after they fell, but these rots in the cases investigated were due to secondary saprophytes which invaded the injured plants. The breaking over was traced to soil, weather, culture, or corn root-worm injury. In the second place the presence of this wilt was not indicated by discoloration of the seedlings on the germinator, although the field in which the observations were made was planted by the ear to the row method and the ears were all observed on the germinator.

*The improved rag-doll germinator as an aid in controlling root, stalk and ear-rots of corn.* B. H. DUDDLESTON AND G. N. HOFFER.

The improved rag-doll germinator, developed in the corn root and stalk rot investigations conducted coöperatively by the Office of Cereal Investigations and the Purdue University Agricultural Experiment Station, has been used with marked success in detecting seed ear infections in corn. In a test of over 14,500 ears at Shelbyville, Indiana, in 1920, 27 per cent showed serious infections of Fusarium spp. and Diplodia. Twelve experimental plots in Shelby County have shown an average decrease of 11.1 per cent, or an equivalent of eight bushels per acre, when Fusarium infested ears which germinated 100 per cent were used to check against the general field planted with apparently disease-free ears. Local strains of dent corn were used in these tests. The range of difference was from 2.5 to 23.8 per cent decrease varying with the different strains of corn and conditions under which they were grown. Some of the seed stocks showed heavier infections than others and a direct correlation seemed to exist between this and the amount of reduction in yield.

*Kernel starchiness as an index of susceptibility to root, stalk, and ear rots of corn.* JOHN F. TROST AND G. N. HOFFER.

Starchy ears of corn of certain dent varieties produce larger numbers of weaker-growing and more root-rot susceptible plants in the field than the plants from ears more horny in composition, irrespective of whether the starchy kernels are infected with species of Fusarium before planting. An experimental test of over 2000 seed

ears supplied in groups of 100 each by prominent Indiana seed corn growers shows that seed ear infections occur in an increasing gradient according to the degree of starchiness of the ears of the various strains. Results from an experimental ear-row plot at Bedford, Indiana, in 1920, wherein only apparently disease-free starchy and horny ears of a yellow dent strain were used, show that the average reduction in initial stand was 4 per cent and in yield 16.4 per cent for the various rows planted with the starchy ears in comparison with the average stand and yield for the rows planted with the ears of horny composition. (Coöperative investigations by the U. S. Office of Cereal Investigations and the Purdue University Agricultural Experiment Station.)

*Three methods of controlling the root, stalk, and ear rots of corn.* G. M. SMITH AND G. N. HOFFER.

Field selection of seed ears of sweet corn from apparently healthy stalks, artificial drying by heat immediately after harvesting the ears, and testing seed ears for germination and infection in the improved rag doll germinator are three methods, any one of which, or all combined, have been found profitable in reducing the amounts of seed-ear infections with Fusarium spp. which cause losses in this crop when used for canning purposes. Field-selected ears of Stowell's Evergreen from vigorous healthy stalks yielded 10 per cent more than the bulk selected ears from the same field. An experimental test of ten artificially dried seed lots averaged 14.6 per cent greater initial stand, 35.5 per cent less barren stalks, and 18 per cent higher yield than the average of 22 plots wherein naturally-cured ears were used. An average of 10 plots in which both apparently disease-free and diseased seed ears were used gives a reduced yield of 9.8 per cent per acre for the diseased seed ears. (Coöperative investigations by the U. S. Office of Cereal Investigations and the Purdue University Agricultural Experiment Station.)

*Resistance as a basis of control of corn root rot.* W. D. VALLEAU.

A study of the extent of ear and seed infection, carried on at the Kentucky Agricultural Experiment Station, on 39 varieties of corn from 27 localities in the United States, indicates that ear and seed infection with *Fusarium moniliforme* is probably universal. No disease-free ears or lots of shelled corn have been found. Ear to row tests were conducted, using the 69 ears reported on in Table I, Bul. 226, Kentucky Agricultural Experiment Station. One month after seeding, 1570 of 1575 plants examined showed distinct nodal discolorations. Records made between October 10 and 15, after the ears were ripe and before a killing frost, showed 1149 of a total of 5036 plants to have died prematurely, an average of 22.8 per cent. There were striking differences in the greenness of the live plants from the various ears. The differences in time of death of the various plants were due to differences in degree of resistance to root rot which each possessed. Ears of corn selected for seed purposes may be graded as to the relative degree of resistance which plants from them show when grown in the sand box germinator. The same relative degree of resistance will be shown when ear to row tests are conducted in the field. Forty-six per cent of the plants from the most susceptible ears selected from 100 seed ears were prematurely dead on October 11, while only 9.3 per cent of those from the most resistant ears were dead at that time. All of the plants from the susceptible ears died before frost, while the live ones from the resistant ears remained alive and green until killed by frost.

*Selection of disease-free seed and seed treatments as possible means of control of corn root rot.* W. D. VALLEAU.

Ears were selected at various periods from the early dough stage to maturity in an attempt to obtain disease-free seed. Thus far no disease-free seed has been obtained by this method. The results obtained indicate that infection takes place before the early dough stage. It probably occurs through the silks and is a result of infection of the exposed silk mass with *F. moniliforme*. Attempts to control corn root rot by seed treatment have given negative results. Various modifications of the hot water treatment and soaking in various chemicals including formalin, copper sulfate, mercuric chloride, Bordeaux mixture, ammoniacal copper carbonate, commercial lime sulfur, barium thiosulfate, calcium thiosulfate, sodium hyposulfite, potassium polysulfide, sodium bisulfite and 95 per cent alcohol for periods up to seven hours have given no control of corn root rot. Practically as much injury resulted to seedlings grown in sand following these treatments as to checks. Field results also indicate that the methods tried give no promise of control.

*Second progress report on the fusarium blight (scab) of wheat.* JAMES G. DICKSON, HELEN JOHANN, AND GRACE WINELAND.

While Fusarium blight or scab did not occur in epidemic form in the winter wheat belt during the past season considerable losses occurred in the spring wheat area, especially in Wisconsin, Minnesota and South Dakota. In 1920 two hundred specimens were received from sixteen central and eastern states. Ninety-eight per cent of these yielded *Gibberella saubinetii* (Mont.) Sacc., as contrasted with 94 per cent in 1919. About 2 per cent of the specimens each year gave *Fusarium avenaceum* (Fr.) Sacc. *F. culmorum* var. *leteius* Sherb. was isolated from a few specimens in 1919, but was not found on the specimens collected the past season. Isolations for the two seasons showed *G. saubinetii* to be the most common organism, although the season of 1920 was much drier than the preceding one. The great difference in perithecial development for the two seasons—51 per cent of the specimens in 1919 and 15 per cent in 1920—suggests that perithecial development in *G. saubinetii* is closely associated with moisture. Results from about 400 field inoculations with pure cultures of the previously mentioned organisms and *F. culmorum* (W. G. Sm.) Sacc. indicate that the highest percentage of infection with all of the organisms occurs during the period of flowering. Initial infection usually occurs through the extruded anthers. After the fungus has become established, it spreads to adjacent tissues. Subsequent rapid progress of the blighting depends upon three or four days of continued warm, humid weather. (Coöperative investigations by the U. S. Office of Cereal Investigations and the Wisconsin Agricultural Experiment Station.)

*The influence of soil temperature on the development of the seedling blight of cereals caused by Gibberella saubinetii.* JAMES G. DICKSON.

The seedling blight of winter wheat caused by *Gibberella saubinetii* (Mont.) Sacc. has been noted most commonly in early sown fields. This parasite has been found to attack corn seedlings also.

Parallel series of clean and infected wheat and corn seedlings have been grown under greenhouse conditions in loam soil held at eight constant soil temperatures at four degree intervals from 8° to 36° C. Uninfected wheat seedlings developed the largest root systems and the heaviest total dry weight at soil temperatures below 16° C. On the other hand, corn seedlings produced the largest root systems and greatest total dry weight at soil temperatures above 20° C. Wheat seedlings from naturally infected

(scabbed) wheat as well as clean seed artificially inoculated did not blight at soil temperatures below 12° C.; severe blighting occurred from 16° to 28° C.; only very little at 32° C., which is about the maximum temperature for the development of the organism, and none at 36° C. On the contrary, corn seedlings from clean seed inoculated with the parasite blighted badly at the soil temperature of 20° C., and below, and did not blight above 24° C. Periodic field plantings using scabbed wheat and clean, inoculated seed and clean seed uninoculated were made from March to June, 1920, at Madison, Wisconsin. In March and April plantings, when the soil was cool, the scabbed and inoculated seed and controls each produced an average of 76 per cent stand. In May plantings, when the soil was warm, the scabbed and inoculated seed produced 32 per cent stand and controls 77 per cent. These field results correlate with greenhouse experiments summarized above. (Coöperative investigations by the U. S. Office of Cereal Investigations and the Wisconsin Agricultural Experiment Station.)

*Growth and germination of Gibberella saubinetii at varying hydrogen-ion concentrations.* E. F. HOPKINS.

The effect of acidity on the growth of the wheat scab organism was determined in three series of liquid cultures using a synthetic medium in which the H-ion concentration was adjusted by means of $KH_2PO_4$, $K_2HPO_4$, $H_3PO_4$ and KOH. The pH values were determined colorimetrically both at the beginning and end of each experiment. The dry weights of the mycelial mats were taken at the end of four, seven and fourteen days. In all three series the amount of growth increased with decreasing acidity from pH 2.5 to a maximum at pH 4.0–4.5. It then decreased to a minimum at pH 5.0–5.5 and rose again to a second maximum, the highest point of which was not determined. When NaOH and $H_2SO_4$ were used to adjust the reaction results were obtained which substantiated those just mentioned. A culture of a Fusarium, not proved to be Gibberella but isolated from scabby wheat, showed a similar depression in the growth-acidity curve.

Using solutions prepared as above, the effect of the hydrogen-ion concentration on spore germination of *Gibberella saubinetii* was also studied and results thus far indicate that conidial germination also shows a double maximum.

*Hydrogen-ion concentration of the soil and seedling infection by Gibberella saubinetii.* E. F. HOPKINS.

The reaction of the soil in seventeen flats in the greenhouse was adjusted to varying degrees of acidity by means of N/1 NaOH and N/1 $H_2SO_4$, which were thoroughly mixed with the soil. After standing some time in order to allow equilibrium to be reached samples were taken from each flat and the hydrogen-ion concentration determined colorimetrically. The flats were then planted with wheat seed which had been treated with a spore suspension from an authentic culture of *Gibberella saubinetii* and the surface of the soil sprayed with the same spore suspension.

Counts of the seedlings as they appeared were made and a marked depression in the curve was noted at a pH of about 5.8 at the end of four days when the number of seedlings was plotted against the hydrogen-ion exponents. Infection in the seedlings first appeared evident ten days after planting. Re-isolations from a number of diseased seedlings produced typical cultures of the organism. At the end of three weeks the greatest amount of infection showed in the most acid (pH = 2.5–3.0) and most alkaline (pH = 3.4–4.0) soils with a minimum in the curve at a pH of about 5.5. This minimum appears to correspond with a minimum in the growth-acidity curve of the

wheat scab organism. Two flats of soil of a pH = 6.4, the original soil, uninoculated showed a perfect stand with no diseased seedlings.

*The so-called take-all disease of wheat in Illinois and Indiana.* H. H. McKINNEY.

This disease recurred in Madison County, Illinois, and in Porter County, Indiana, in 1920. In Illinois the disease was severe in 1920 but was less extensive than in 1919. This was probably due to the fact that the majority of farmers did not sow the few varieties which showed the disease the previous year. The first indications and characteristic symptoms of the disease consist in retarded spring development followed by excessive tillering. No lesions or organisms were found constantly associated with the disease during this early spring stage. A little later, lesions develop and a species of Helminthosporium has been found rather closely associated with the disease, and there is a suggestion that so-called take-all in Illinois and Indiana may be an unusual manifestation of the Helminthosporium disease of wheat present in many sections. While pathogenicity tests have shown the Helminthosporium to be pathogenic on wheat, this organism has not yet produced the characteristic field symptoms of the so-called take-all. Further work is necessary before the cause of this disease can be definitely assigned to this organism. The most promising means for controlling the disease as it is understood at present lies in the use of resistant varieties. Red Wave and May varieties and a strain of Turkey are, thus far, not susceptible to the disease, while the white chaffed, red-kerneled type of Red Cross (Salzer's Prizetaker) and Illini Chief are very susceptible. These investigations were conducted by the Office of Cereal Investigations at Granite City, Ill., and Madison, Wis.

*Helminthosporium and wheat foot-rot.* F. L. STEVENS.

In an adaptation of the rag-doll seed tester, which allows of the use of seedlings under aseptic conditions and variation of moisture and temperature as desired, inoculation by spores of *Helminthosporium* upon the uninjured sheath was followed within 24 hours by entrance of the mycelium into the host cells, and within 48 hours by a browned, diseased spot visible to the naked eye. Subsequently, when conditions favored, the mycelium invaded the innermost leaves and caused general rotting and death. When inoculated upon roots there was general invasion of the cortex with very slight discoloration. Aside from the Helminthosporium originally isolated several variant, closely related types have been isolated that have the same infecting ability, which is also possessed by all (many) cultures sent to me under the names *H. teres*, *H. avenae*, *H. gramineum* and even *H. interseminatum*. Infection is through the middle lamellae. The mycelium forms appressoria, the middle and inner lamellae adjacent to it swell, and they and the adjacent cellulose walls change in stain reactions. On the inside of the host cell callus-like bodies develop. Similar results are had in inoculations in soil. A geniculate spored Helminthosporium produced abundant mycelial invasion but extended to only a few cells. An Alternaria common on wheat grains produces the early symptoms of infection but was not seen to gain entrance to the wheat cells. Infection by the foot-rot Helminthosporium was secured on corn, barley, rye, corn-fodder, Sudan grass and millet.

*The effect of certain chemicals especially copper sulfate and sodium chloride on the germination of bunt spores.* NOEL F. THOMPSON.

Experiments were conducted at Pullman, Wash., and at Madison, Wis., to determine the concentration of the solution and the length of treatment necessary to cause the death of bunt spores (*Tilletia tritici* (Beij.) Wint. and *T. laevis* Kühn). The chem-

icals and the concentrations generally employed in seed treatments were used and also various dilutions and combinations of these. Finely sifted spores were agitated in a relatively large amount of the solution. The spores were then caught on filter paper and, after drying, were transferred to the surface of moist soil to germinate. The following table gives the relative amount of germination of *T. triciti* spores after ten-minute treatments with different chemicals. O indicates no germination, 1, a very small per cent, 2 and 3, intermediate, and 4, an abundant germination.

| CHEMICAL | STRENGTH LBS. TO GALS. | RELATIVE GERMINATION DURING SIXTEEN DAYS | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Water | | 0 | 0 | 0 | 2 | 4 | | | | | | | | | | | |
| NaCl | 1–5 | 0 | 0 | 0 | 2 | 4 | | | | | | | | | | | |
| CaO | 1–5 | 0 | 0 | 0 | 2 | 4 | | | | | | | | | | | |
| $CuSO_4$ | 1–5 | 0 | 0 | 0 | 0 | 1 | 3 | 4 | | | | | | | | | |
| $CuSO_4$ and NaCl | 1–1–100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | | | |
| " | 1–1–50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | | | |
| " | 1–1–25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| " | 1–1–5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| HCHO | 1–160 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 4 | | | | |
| " | 1–80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| " | 1–40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |

The strongest copper sulfate solution used did not inhibit growth but only retarded it. This was true whether the treatment was one minute or one hour. A relatively dilute solution of copper sulfate and sodium chloride practically inhibited all growth. The results with *T. laevis* were essentially the same as with *T. triciti*.

*Chemical dusts for the control of bunt.* W. W. MACKIE AND FRED N. BRIGGS.

The writers, confirming the results of other investigators, have shown that the commonly employed methods of seed disinfection involving the use of bluestone and formaldehyde frequently are injurious to the germination of the seed and to the development of the seedling. Further, where the season for seeding grain is very short, the present treatments interfere with seeding operations and cause the loss of valuable time because the seed cannot be treated previous to the seeding period. In case seeding is interrupted by rain any treated seed stored damp may be damaged. Since 1918, the writers have conducted experiments with flowers of sulphur and the dusts of copper sulphate and copper carbonate for the prevention of bunt. All experiments were made with Little Club wheat, inoculated with *Tilletia tritici* and sown in rod rows which gave an average of over 500 heads. Sowings were made in duplicate. In 1919, flowers of sulphur gave the following results where quantities of one-half to two quarts were mixed with 140 pounds of seed.

| TREATMENT | | SMUTTED HEADS AVR. PER CT. |
|---|---|---|
| Seed heavily smutted. | Not treated | 84.1 |
| " " " | Mixed with flowers of sulphur | 41.5 |
| " " " | Bluestone (1–4) | 21.9 |

In 1920 flowers of sulphur gave the following results when 25 to 100 pounds were mixed with 100 pounds of seed:

| TREATMENT | | SMUTTED HEADS AVR. PER CT. |
|---|---|---|
| Seed smutted | | |
| 1:750 by weight. | Not treated | 61.8 |
| " " " | Sulphur* | 6.3 |
| " " " | Bluestone (1–4) | .2 |
| " " " | Formaldehyde (1–4) | .0 |

* Varying amounts of sulphur gave practically the same reduction in smut.

In 1920, results from copper sulphate and copper carbonate dusts applied at the rate of two ounces per bushel were as follows:

| TREATMENT | | SMUTTED HEADS AVR. PER CT. |
|---|---|---|
| Seed smutted | | |
| 1:750 by weight. | Not treated | 6.2* |
| " " " | Dusted with copper sulphate plus calcium carbonate (1–1) | .0 |
| " " " | Dusted with copper carbonate | .0 |
| " " " | Bluestone (1–4) | .1 |
| " " " | Formaldehyde (1–40) | .0 |

* Low per cent of smut in check rows was due to late sowing.

The results reported in this abstract were obtained by the California Experiment Station in coöperation with the U. S. Office of Cereal Investigations.

*The regional occurrence of Puccinia graminis on barberry.* E. C. STAKMAN, R. S. KIRBY AND A. F. THIEL.

It has been observed frequently that the common barberry does not rust in the Southern States and on the Pacific Coast. The Office of Cereal Investigations of the United States Department of Agriculture, coöperating with State experiment stations, undertook to ascertain the limits of barberry infection and to determine why infection did not occur in the South. It was found that east of the Rocky Mountains barberry infection is most prevalent and most severe north of 40 N. lat., although at high elevations in certain regions there was heavy infection as far south as 37°. The line representing the southern limit of the barberry infection area is quite irregular. It was found that barberries would not become infected in the Southern States when they were inoculated with teliospore material which had been developed in the South. On the other hand, when they were inoculated with teliospores from the North, they became very heavily infected. Excellent infection was obtained as early as March 16, by using northern material. Teliospores from the South which had been kept in the North during the summer and fall, however, caused infection in the South, while north-

ern teliospores which had been kept in the South did not cause infection. Teliospores formed in the fall in the South caused infection the following spring. Numerous germination tests were made and the results of the germination tests correlated with the facts observed regarding infection. Evidently, therefore, the reason why barberries do not become infected in the South is not because conditions are unfavorable for infection, but because practically no teliospores are viable in the spring.

*The aecidium of the orange leaf rust of wheat, Puccinia triticina.* H. S. JACKSON AND E. B. MAINS.

In the spring of 1919, ten collections of wintered telia of *Puccinia triticina* were germinated and sown on 48 species included in 19 genera of the families Ranunculaceae, Boraginaceae, and Hydrophyllaceae. The results were negative except in the case of two species of Thalictrum, upon which pycnia were produced. In the spring of 1920, 37 collections of wintered telia were germinated and sown upon 14 species of Thalictrum. Infection resulting in the development of pycnia or aecia was obtained in 84 instances upon 12 of these species. The most vigorous development of aecia was obtained on four exotic species. Infection was only occasionally obtained on the native species used with but a weak development of aecia. The collections of telia giving infection were from Pennsylvania, West Virginia, North Carolina, South Carolina, Alabama, Georgia, Mississippi, Tennessee, Kentucky, Indiana, Michigan, Illinois, Minnesota, Iowa, Missouri, Louisiana, Texas, Arizona, California, Washington, and Idaho. Aeciospores obtained from 20 of these cultures were sown back upon seedling wheat, producing in every case uredinia typical of *Puccinia triticina.* (Coöperative investigations by the Purdue University Agricultural Experiment Station and the U. S. Office of Cereal Investigations.)

*Two strains of Puccinia triticina on wheat in the United States.* E. B. MAINS AND H. S. JACKSON.

Shortly before harvest in 1919, certain varieties of wheat showed a high degree of resistance to *Puccinia triticina* as grown in the wheat nursery at La Fayette, Indiana. These included Kanred (P. 762), P. 1066 (Kans., 2415) P. 1068 (Kans. 2414), and four selections of a hybrid, Turkey x Bearded Minnesota, received from the Kansas Experiment Station, together with Malakoff, C. I. No. 4898. When certain uredinial cultures of this rust were sown on seedlings of these varieties in the greenhouse a difference in reaction was noted. Kanred, P. 1066, and P. 1068, were fairly heavily infected by all cultures in the seedling stage. The explanation of this has been found to be due to a difference in the susceptibility of these varieties according to maturity. They are moderately susceptible in the seedling stage, becoming highly resistant as they mature. The varieties Malakoff and the four Turkey x Bearded Minnesota hybrids, however, reacted differently, showing resistance in the seedling stage to all but two of the cultures used. These two cultures were obtained from Murfreesboro, Tenn., and Normal, Okla., and were found to infect the Malakoff and Turkey x Bearded Minnesota selections fairly heavily. During 1920, a number of additional uredinial cultures were sown on these five varieties, resulting in a separation of these cultures into two groups by their ability or inability to infect selections of Malakoff and Turkey x Bearded Minnesota. In field sowings a somewhat similar differentiation of *P. triticina* into two strains has been noted. Both strains have also been obtained from the aecia of this rust developed on Thalictrum. (Coöperative investigations by the Purdue University Agricultural Experiment Station and the U. S. Office of Cereal Investigations.)

*The nematode disease of cereals.* A. G. JOHNSON AND R. W. LEUKEL.

In experiments covering two years at the Arlington Farm of the United States Department of Agriculture, Arlington, Virginia, this disease has been found to attack wheat, rye, emmer and spelt severely. Although, in a few cases, rudimentary galls formed on oats and barley, these two cereals have proved to be practically immune. Byars found that the nematode (*Tylenchus tritici*) remained alive for over ten years within the dry galls. The nematodes from ground galls have been kept in a dry place for over a year and are still alive. In moist soil, they die in less than a year. Soil badly infested in 1918 was sown to grass for a year and wheat sown in the fall of 1919 did not become infected. Dissemination is chiefly through infested seed and straw. In our experiments the nematodes moved horizontally in the soil only about four inches. Vertically, however, they moved up from a depth of twelve inches. The first symptoms of the disease in the field become evident in the fall about three weeks after the wheat is sown. This shows definitely that general infection of winter wheat occurs in the fall under Virginia conditions. This varies from the supposed condition in Germany where, as stated by Marcinowski, infection takes place in the spring. For two years a series of twenty-five wheat varieties have been tested for relative susceptibility. Only one, namely Kanred, has shown consistent resistance. The different varieties of emmer, spelt and rye showed rather high susceptibility. Control measures require clean seed, rotation, and keeping infested material off land at least one year previous to sowing wheat.

*Loss from rye ergot.* EDITH K. SEYMOUR AND FRANK T. MCFARLAND.

Observations and exact counts, initiated by Dr. L. R. Jones in 1918 and continued during 1919 and 1920, show that the loss caused by ergot (*Claviceps purpurea* (Fr.) Tul.) in rye is represented not only by the actual number of sclerotia but also by a large number of blasted kernels and empty florets. These blasted kernels and empty florets, present in ergotized and unergotized spikes, are always greater in number in the ergotized spikes. Of 730 ergotized spikes 47 per cent of the florets either held blasted kernels or were empty and 10 per cent held sclerotia. Of 651 unergotized spikes only 31 per cent of the florets either held blasted kernels or were empty. Verification of the wide penetration of the fungus through the diseased spikes was shown in 24 spikes by the abundance of conidia in 70 per cent of the florets, of which only 21 per cent showed sclerotia. The average length and weight of the ergotized spikes was compared with that of the unergotized spikes. In all cases but one the diseased spikes were shorter in length and lighter in weight. (Coöperative investigations by the Wisconsin Agricultural Experiment Station and the U. S. Office of Cereal Investigations.)

*Infection experiments with Claviceps.* FRANK T. MCFARLAND.

During the summer of 1920 careful cross inoculation experiments were performed to ascertain, if possible, the interrelations of the ergots (Claviceps) of the different grasses and cereals. While the results obtained thus far are somewhat fragmentary, it is deemed wise to give a preliminary report at this time. Successful inoculations from rye upon rye have easily been secured. In these trials with rye equally good results have been obtained by using conidia from any of three sources: (1) the honey dew from ergotized florets, (2) the surfaces of mature sclerotia, (3) pure cultures from agar slopes. In all cases success was limited to infections made when the floral glumes were wide open, negative results following inoculations made at both earlier and later stages. Successful inoculations have been secured upon rye with Claviceps conidia

from the honey dew stages of each of the following: *Bromus inermis*, *Agropyron repens*, *Poa pratensis*, and *Arrhenatherum elatius*. With wheat it has been more difficult to secure infection, although positive results in a few cases have come when conidia were used from either rye, *Arrhenatherum elatius*, *Poa pratensis*, or *Agropyron repens*. Pure cultures of the rye strains also gave infection. In general cross inoculations have given a higher percentage of success where made from one of the above grass species to another than where made from grass to rye.

*Occurrence of Rhyncosporium on Dactylis glomerata and Bromus inermis.* CHARLES DRECHSLER.

At Madison, Wis., during the month of May, 1920, *Rhyncosporium secalis* (Oud) Davis was found attacking *Dactylis glomerata* and *Bromus inermis*, the lesions produced being altogether similar to those characteristic of the disease of rye and barley caused by the same fungus. As the individual plants of *Dactylis glomerata* found affected were relatively few in number, this host, perhaps, cannot be regarded as a highly congenial one. On *Bromus inermis*, however, the lesions were moderately numerous, the disease here being present in the same degree of abundance as on rye and barley growing in the vicinity. No records of the occurrence of the parasite on these two hosts either in America or elsewhere has been found. (Coöperative investigations by the Wisconsin Agricultural Experiment Station and the U. S. Office of Cereal Investigations.)

*Two sclerotium diseases of rice.* W. H. TISDALE.

Studies by the U. S. Office of Cereal Investigations at the Rice Experiment Station, Crowley, La., revealed two unreported Sclerotium diseases of rice, namely:

(1) Seedling blight (*Sclerotium rolfsii* Sacc.). Blighted seedlings observed at Crowley, La., June 12, 1919. Destructive to germinating seed and young seedlings. Stand of plants decreased as much as 50 per cent on inoculated soil. Strains of *S. rolfsii* from soy bean and oat grass produced very little effect on the stand of rice, while a strain from wheat was as parasitic as the rice organism. Sclerotia survive winter weather and irrigation. Irrigation checks the disease. Cultivation reduces amount of fungus in soil.

(2) Stem rot (*Sclerotium oryzae*) Catt.?) Cattaneo described *S. oryzae* in Italy in 1877. Sclerotia smaller than the American form. Miyake reported *S. oryzae* Catt. as causing a serious disease in Japan in 1909. Found at Crowley, La., on old rice straw in spring of 1919. Noted as serious disease of Early Prolific rice August 5, 1920. Found in other varieties later. Fungus attacks stems at the water line. Plants weaken and lodge easily. Grain fails to fill normally. A fine, white mycelium and numerous spherical, black sclerotia, 250 microns in diameter develop in the stem cavity and diseased tissues.

*Rice straighthead and its control.* W. H. TISDALE AND J. MITCHELL JENKINS.

For the past two years the U. S. Office of Cereal Investigations has been conducting experimental work at the Rice Experiment Station at Crowley, La., on "straighthead," a physiological disease, which annually causes serious damage to the southern rice crop. The disease is characterized by sterile or partially sterile panicles which stand straight. The leaves are darker green and somewhat stiffer than normal. Flower parts fail to develop in various degrees. The single sickle-shaped glumes are characteristic. The disease is more prevalent on virgin soil and on soil that has been planted to dry land crops in immediately preceding years. Apparently certain stages of the

decay of organic matter leaves the soil in such physical condition that practically all the air is excluded when water is applied. A large system of primary roots develops but few secondary roots and root hairs. Thus normal nutrition is upset. If the soil is drained during certain parts of the irrigation period so as to permit root aeration, normal root systems develop and a good crop of rice is produced. If, however, this type of soil is not drained, serious damage may be expected from "straighthead."

*The control of peach brown rot and curculio.* J. A. McCLINTOCK.

In the coastal plain of Georgia neither sprays nor dusts control curculio or brown rot satisfactorily. Data were collected at fourteen commercial peach orchards, totalling over 300,000 trees. An average of 50 per cent of the fruit was wormy and there was 10 per cent of brown rot on uninjured fruit. Adjoining plats of 300 trees each gave the following results:

Plat 1: sprayed 4 times with atomic sulphur, 20 gallons; lime, 20 lbs.; powdered arsenate of lead, 3 lbs.; and water, 200 gallons gave 59 per cent wormy, 15 per cent wormy and rotting, 1 per cent rotting, no scab, and 25 per cent sound fruit.

Plat 2: dusted 4 times with 80 per cent sulphur, 15 per cent lime, using 100 lbs. of dust to 500 trees at an application, gave 68 per cent wormy, 6 per cent wormy and rotting, 1 per cent rotting, no scab, and 25 per cent sound fruit. In isolated orchards of the coastal plain section three applications of spray resulted in 10 per cent wormy and less than 1 per cent rotting fruit.

*Blossom blight of the peach.* MEL. T. COOK.

This disease is due to *Sclerotinia cinerea* (Bon.) Schrot. It was exceptionally severe in New Jersey in 1919 and also very severe in 1920. It is much less severe on young than on old orchards, but apparently has no connection with the mummied fruits. It was very severe in the state experimental orchards from which rotten fruits of the preceding year had been removed. It apparently spreads from cankers formed on the wood of the preceding year. Twigs that are completely girdled wither and die. The vitality of those that are partially girdled is greatly reduced. Cankers on the older wood are of little importance. The cankers are easily confused with scab cankers. The disease can be greatly reduced by the pink bud spray.

*Second progress report on apple scab and its control in Wisconsin.* G. W. KEITT.

During the past season the work on apple scab was continued and extended, special attention being given to studies of the development of fungus, host, disease, and control, and to climatic conditions.

The discharge of ascospores of *Venturia inaequalis* (Cke.) Wint. was carefully followed at Madison and Sturgeon Bay. At Madison the first discharge was noted on April 23 and the last on June 12. The heaviest discharges occurred between May 11 and May 24. The apple buds separated in the clusters about May 17–19. Developments were probably considerably influenced by a dry period from May 1 to May 9.

At Sturgeon Bay the first ascospore discharge was noted on May 20 and the last on June 30. The heaviest discharges occurred between June 8 and June 17. The apple buds separated in the clusters about May 29–30. Developments were probably considerably influenced by a long dry period in early May and another from May 24 to June 6.

At Sturgeon Bay lime-sulphur (liquid) and Bordeaux mixture controlled scab satisfactorily when applied comparatively according to the standard four-spray schedule: (1) May 29–30 ("pink"), (2) June 9, (3) June 21–22, and (4) August 6. An additional

early treatment on May 24 was of little value, due to the unusually long dry period which followed. The development of scab during the season was less severe than usual.

*Leaf scorch or mollisiose of strawberry.* R. E. STONE.

A very common disease of the cultivated strawberry is found in nearly all districts of southern and eastern Ontario. It is of most importance the second year after transplanting, making the plants weak and unable to successfully winter over for the second crop. In early stages the leaves show irregular purple spots. These enlarge and coalesce, involving the entire leaf, and may also be found on the petiole. Later the spots become cinereous and the leaves take on a dried scorched appearance. Whole plants and often the entire patch appear as though burned over by fire. An examination of the purple spots and cinereous areas shows the presence of sub-cuticular acervuli containing hyaline, muticate, two-celled spores. The fungus has in the past been called *Marssonia potentillae* (Desm) Fisch. Inoculations with pure culture from these spores produce the typical disease. *Marssonia potentillae* (Desm) Fisch. may winter over in the conidial stage of green leaves and may even be found in viable condition on dead leaves. On the dead dry leaves that have been attacked by this organism an ascigerous stage develops. This ascigerous stage has been determined as *Mollisia earliana* (E. & E.) Sacc. The following facts show the relations of the two forms:

(1) The Mollisia follows the Marssonia.

(2) Strawberry plants infected with ascospores developed the Marssonia spot.

(3) Ascospores planted singly develop Marssonia colonies in culture.

(4) Marssonia developed from single ascospores is capable of infecting the strawberry leaves, giving rise to typical leaf scorch.

Since *Mollisia earliana* is the perfect or ascigerous stage of the fungus, the causal organism should be referred to as *Mollisia earliana* (E. & E.) Sacc.

*Rhizopus sp. associated with a decay of unripe strawberries in the field.* L. E. MELCHERS.

In 1919 and 1920, the writer observed that unripe strawberries in the field were being attacked by Rhizopus. The fruit was about three-fourths grown, and the berries were in the white stage (just before the berries show a pink or red color). Wherever the berries touched the soil infection occurred. The decayed spots became soft and slightly brown. In some fields from 25 to 35 per cent of the fruit was unsalable. Seasonal conditions without doubt have a great influnece on the occurrence of this trouble. A few days to a week of cloudy, wet weather, just before the berries begin to turn pink, is the most favorable for infection. A few bright days will stop this injury. Prior to 1919, no report seems to have been made which shows that Rhizopus has been found on unripe fruit in the field.

*Tissue breakdown in fruits and vegetables.* RAY NELSON.

Certain market fruits and vegetables are seriously affected with a disease in which lesions of various kinds occur. The diseases known as "black leaf speck" of cabbage, "red heart" of Iceberg lettuce, and various surface spots of grapefruit, orange and lemon belong in this group. The disease may be classed as a tissue breakdown and commonly occurs under conditions of poor ventilation in storage and transportation. It has been reproduced typically for all of the above hosts by imitating the conditions prevailing in transportation and storage.

*The effect of incipient decay on the mechanical properties of airplane timber.* REGINALD H. COLLEY.

Standard tests conducted at the University of California by the Bureau of Plant Industry in coöperation with the U. S. Forest Service indicate marked differences in the effect of different fungi on the mechanical properties of airplane timber. Pieces of Sitka spruce and Douglas fir showing incipient decay were tested against matched sound pieces. The effect of *Fomes pinicola, Fomes laricis* and *Polyporus schweinitzii*, which may be grouped together, was decidedly more marked than that of *Trametes pini*. Test sticks taken many feet ahead of the typical rot showed the weakening effect of *P. schweinitzii*, while sticks infected with *T. pini* gave as high or higher results than sound wood. Lumbermen have long recognized that wood infected with *T. pini* is strong even in the early pocket stage. Interpretation of results is difficult. Correction constants figured for sound wood are probably inapplicable to infected wood. Such variables as resin infiltration which raises the specific gravity of an infected stick above the normal specific gravity for sound wood must be considered. Results point to need for more careful inspection and diagnosis of incipient decay in forest and mill to prevent the expense of working and finishing defective stock and its inclusion in the airplane.

*Valsa poplar canker.* ALFRED H. W. POVAH.

This disease, under the name *Cytospora chrysosperma* (Pers.) Fr. has been reported from the Southwest by Long and from the Northwest by Hubert. It has been found near Syracuse, N. Y., to cause serious injury and in some cases death to *Populus tremuloides* and *P. grandidentata* when weakened by fire. Field studies show infection of 68.4 per cent and mortality of 36.9 per cent. The perfect stage (*Valsa sp.*) has been found on the trunks of infected trees. Inoculation experiments with pycnospores on cuttings of *P. tremuloides, P. grandidentata* and *P. caroliniana* have resulted in the production of typical pycnia, bearing the characteristic red spore horns, and the death of the cuttings. Cuttings not inoculated but kept in the laboratory where material bearing spore horns was exposed soon became infected and were killed.

*Notes on the Peridermiums of pines in Colorado and California.* ELLSWORTH BETHEL.

The writer gives a summary of his observations, and culture work on western Peridermiums, covering a period of more than a score of years. New aecial hosts are recorded for *Peridermium filamentosum* Pk., *P. stalactiforme* Arth. & Kern, and *P. Harknessii* Am. Auct., and it is shown that these rusts have the same telial hosts, namely, species of Castilleja, Orthocarpus, Pedicularis, Adenostegia, and other genera of the Scrophulariaceae. The hosts, habit, and distribution of *Uredo coleosporioides* Pk. have been studied for many years, and the conclusion reached that it may represent the uredinial stage of any one, or all of the three forenamed caulicolous Peridermiums. Many important facts are given relative to *Peridermium cerebrum* Pk. in California, including its Cronartium on oak, the results of cultures, and data pertaining to its life cycle. Its range has been extended to the Mexican border, and new aecial and telial hosts are added. *Coleosporium ribicola* (C. & E.) Arth. and *C. solidaginis* (Schw.) Thum. are discussed. The range for both rusts has been extended, and new telial hosts are recorded. The writer exhibited a number of interesting specimens of Peridermiums to show the initial point of infection, and the time required to produce aecia; also specimens showing the nature of Cronartium uredinia blisters on Ribes, Quercus, and Castilleja, by which means the Cronartiums overwinter.

*Investigations to determine the identity of a cronartium on Ribes in California.* ELLSWORTH BETHEL AND GILBERT B. POSEY.

Extensive explorations were conducted by the writers the past season in California, to determine the identity and potentiality of a widely distributed Cronartium on native currants and gooseberries. Further investigation of the two large areas found in 1919 indicate that it all belongs to the pinon blister rust, *Cronartium occidentale* Hedgc., Bethel & Hunt. In the northern region from Mono Lake, Cal., to Minden, Nev., the Cronartium is ubiquitous on Ribes in the forests of *Pinus monophylla* Torr. In this region the attack of the Peridermium on pinon pines probably surpasses in virulence that of any other known Peridermium, differing in this respect from the very rare and feeble attack as found in Colorado. Sugar pine and other white (5-needled) pines, growing in close association with both the aecial and telial stages of the rust, were found to be free from the disease. In the southern region about Monrovia, and Pasadena, Cal., the rust seldom produces telia, and these so poorly developed as to be scarcely functional. However, the uredinial infection is so heavy as to cause an early defoliation of the Ribes plants. Investigations by the senior writer in February indicate that the rust overwinters largely, if not entirely, in the form of uredinial blisters on leaves which survive through the winter, thus obviating the necessity of an alternate host. Thus far no evidence has been obtained of the presence of *Cronartium ribicola* on the Pacific Coast.

*Lightning injury in Hevea brasiliensis.* CARL D. LARUE.

Lightning rarely manifests itself on the Para rubber tree (*Hevea brasiliensis*) in tearing or breaking of the trunks or branches. Usually a single small branch at the top of the tree dies first. From this point the death of the branch continues downward until the trunk is reached, then the trunk dies back until the root is reached and finally the whole tree is killed. Several days may elapse from the time the injury is first visible until the whole tree is dead. The progressive death of the tissues is extremely suggestive of invasion of the tree by some destructive organism. The injury has been attributed to Diplodia and the supposedly guilty organism named *Diplodia rapax.* Cultures by the author showed Diplodia to be the only organism constantly present but this is now known to be secondary and not the cause of the death of the tree. The injury is most pronounced in the cambium region. Here the tissue becomes a deep purple in color and decays with great rapidity, making it easy to trace the progress of the injury. The purple coloration is regarded by the author as diagnostic for this type of injury. Frequently trees surrounding the dying tree show injury in a lesser degree which develops later than the tree most seriously injured, thus suggesting the spread of an organism from one tree to the others.

*Influence of temperature on the development of mosaic diseases.* S. P. DOOLITTLE.

Preliminary experiments, while not permitting definite conclusions, indicate that temperature may influence the development of mosaic diseases. Cucumber plants were inoculated with mosaic while growing at soil temperatures ranging from 18° to 30° C., in three houses whose air temperatures were 18°, 24° and 30° C. At soil temperatures between 22° and 27° C. the percentage of infection was the same, although the incubation period increased with lower air temperatures. Increasing the soil temperature from 27° to 30° C., regardless of air temperature, reduced the incubation period from six to three days and produced a higher percentage of infection accompanied by symptoms of a new type. A few cases of mosaic developed at a soil temperature of 18° C. when the air was above 20° C., but with lower air temperatures

the disease did not develop. The suggestion that the development of diseases of the mosaic type may be influenced by climatic conditions is strengthened by field observations upon aster yellows. Aster plants growing on the same plat in 1919 and 1920 showed in the earlier year almost 90 per cent yellows as contrasted with less than 1 per cent last summer. The notable climatic differences were in temperature and moisture, 1919 being warm and moist and 1920 relatively cool and dry.

*The relation of wild host plants to the overwintering of cucurbit mosaic.* S. P. DOOLITTLE.

Recent investigations indicate that cucurbit mosaic is transmissible to plants outside the Cucurbitaceae and that certain of these plants may carry the disease over winter. Mosaic has been transmitted from cucumber to milkweed, *Asclepias syriaca*, pepper, *Capsicum annuum*, and *Martynia louisiana*, and from these plants to cucumber. There is also some evidence that pigweed, *Amaranthus retroflexus*, is susceptible to cucumber mosaic. Field observations indicate that the milkweed, being perennial, is probably an agent in overwintering mosaic, although apparently less important than the wild cucumber. The transmission of mosaic through the seed of the wild cucumber, *Micrampelis* (*Echinocystis*) *lobata*, is established, field observations confirming the experimental evidence. Surveys in Wisconsin and Illinois indicate that the distribution and severity of the disease is directly related to its occurrence on the wild cucumber in the same locality. During 1920 efforts were made to control mosaic by eradicating the wild cucumber over areas of one to two square miles, located in Wisconsin, Illinois, and Indiana, the latter in coöperation with the Indiana Experiment Station. In some cases the disease was but partially controlled, owing apparently to infection from mosaic milkweed, but results in other localities indicate that combined eradication of the wild cucumber and milkweed may be of practical value in controlling mosaic.

*Overwintering of mosaic of annuals.* J. A. MCCLINTOCK.

In mosaic diseases of potatoes, sugar cane and poke it has been proven that the causal entity is carried over in a living root or stem, but in mosaics of annuals like tobacco, pepper and tomato, where the root dies and the seed does not seem to carry the causal entity, how is the disease producing entity carried over from season to season? Thus far the writer has been unable to carry the causal entity over with sucking insects.

*The relation of mosaic disease of cucumbers to pickling.* MARGARET B. CHURCH.

*Overwintering of mosaic on species of Physalis.* R. F. CRAWFORD.

The question as to how mosaic of tomatoes lives over winter has never been definitely settled. It is generally known that it does not live over in the tomato seed. Mosaic from the tomato has been transferred to the following wild Solanums occurring in Iowa: *Solanum dulcamara*, *S. nigrum*, *Physalis longifolia*, *Nicandra physalodes* and *Datura stramonium*. These wild Solanums are commonly found growing in waste places as fence corners and vacant lots. Among these Solanums, *Physalis longifolia* and *Solanum nigrum* are most generally distributed. Mosaic occurs on all our cultivated Solanums, except egg plant, namely: on potato, tomato, pepper, and ground cherry. It occurs in the field on some of our wild Solanums, *Solanum nigrum* and *Physalis longifolia*. *Physalis longifolia* is perennial and mosaic has been transferred from its root stalks to tomatoes and peppers. This species of Physalis is therefore an especially dangerous weed about fields or gardens where cultivated Solanums are grown.

*Mosaic of sugar beets.* W. W. ROBBINS.

Mosaic occurs in steckling and seed beet fields of northern Colorado. Mosaic plants of the type showing mottling throughout do not occur in commercial fields except those in close proximity to affected stecklings or seed beets. In most commercial fields there is a small percentage of beets characterized by asymmetrical dwarfing and mottling. The disease apparently is not seed transmitted. The infectious principle retains its vitality in the steckling throughout the silo period. Numerous proximity studies in the field show that diseased mothers are centers of infection. Mosaic symptoms vary with the conditions of growth. Mottling is the characteristic symptom. Malformation may or may not be associated with mottling. Phloem-necrosis has been observed in mosaic leaves. An abnormal accumulation of starch in malformed mosaic leaves is a constant symptom. Affected mother beet leaves are often abnormally thick and brittle. Cases of apparent recovery from mosaic have been observed. Studies to date indicate that control measures consist in separation of steckling and seed fields.

*A dry rot of the sugar-beet caused by Corticium vagum.* B. L. RICHARDS.

A serious and apparently undescribed rot of the sugar-beet has been observed during the past season in a number of beet fields in northern Utah and southern Idaho. The disease, as it appears in the field, is confined to somewhat definitely delimited areas wherein every beet may become infected. The roots of the diseased beets show circular lesions characterized by very prominent alternating light and dark brown concentric rings. The disease is typically a dry rot. In the later stages a deep pocket, partly filled with a dry pulp composed of mycelium and decayed host tissue, occurs at each point of infection. With numerous points of attack the beet by harvest time may be converted into a dry pithy mass. Numerous isolations from sugar-beets, taken from a number of fields, have given what, from coöperative studies, appears to be a single strain of *Corticium vagum* B. & C. Inoculation shows this strain to be extremely virulent, and lesions have been produced on normal healthy beets with unusual uniformity. Similar inoculations with two additional strains of *Corticium vagum* obtained from other hosts have given only negative results. So far as has been observed, the fungus is confined in its early parasitic activity to the parts of the beet below the surface of the soil.

*A new phoma disease of cotton.* JOHN A. ELLIOTT.

A hitherto unreported Phoma disease of cotton appeared in June, 1920, in west-central Arkansas along the Petit Jean river. The disease made very rapid progress during a period of cool, wet weather. All plants were killed in small areas, in some of the more severe centers of infection; in other places the stand was greatly reduced. A change in weather conditions abruptly checked the progress of the disease and a great many attacked plants recovered. Scars of the lesions made by the disease could be found in infected fields throughout the summer. The pathogen was isolated and successful inoculations made both on wounded and unwounded tissues. High humidity is essential to the spread and progress of the disease. It attacks all parts of the plant above the soil and is very rapid in its advance through the tissues.

*Treatment of tobacco seed and suggested program for control of wildfire and angular-spot.* F. D. FROMME AND S. A. WINGARD.

Tobacco seed from affected seed pods, as well as that which has been artificially contaminated with cultures of the wildfire and angular-spot organisms, has been made sterile by treatment with formaldehyde, as shown by subsequent plating on nutrient

agar. The concentration found most satisfactory is a two per cent solution and the time of exposure fifteen minutes. There has been no apparent injury to germination from this treatment when followed by thorough washing and drying, and seed so treated may be stored several months if necessary. In practice a dilution of one ounce of forty per cent formaldehyde in one pint of water (approximately 2 per cent) is employed. Seed are treated in mason jars fitted with wire screen covers to facilitate washing and are dried rapidly by means of a hand centrifuge fitted with perforated seed containers. Seed treatment should be supplemented by (a) the use of new cloth for the plant bed cover or sterilization of the old cloth, (b) rotation and burning or steaming of the bed, (c) field rotation.

*Inheritance of disease resistance to Thielavia basicola.* JAMES JOHNSON.

Crosses have been made between varieties of tobacco which are resistant and susceptible to *Thielavia basicola* (B. and Br.) Zopf. The principal studies have been conducted with the susceptible White Burley variety and the resistant Little Dutch type. The first generation of a cross between resistant and susceptible types is intermediate in resistance. The second generation shows individuals of all grades of resistance, from those even more resistant than the resistant parent to others as susceptible as the susceptible parent. Selected individuals in the third generation may continue to vary while others seemingly breed true for the resistant character. Susceptibility is apparently the recessive condition. The inheritance of disease resistance does not seem to follow any simple Mendelian ratio but behaves in a manner which may be best explained by the multiple-factor hypothesis. Practical use is being made of these studies in introducing the resistant character into susceptible commercial types.

*A new seedling disease of tobacco.* C. M. SLAGG.

In June, 1918, a disease of tobacco consisting of leaf spots and stem browning of seedling plants was observed in Fayette County, Ky. Isolations yielded a fungus closely resembling *Fusarium affine* Faut. & Lamb. Inoculations with this fungus upon tobacco seedlings in the greenhouses at Madison, Wis., reproduced the field symptoms on leaves and stems. Reinoculation with single spore isolations of this fungus produced a distinct spotting and disintegration of the leaf tissues under moist conditions. The disease due to this parasite exhibits a variety of symptoms, ranging from a type of damping off, in very humid air, to a slight browning or girdling of the stems, in less humid air. The fungus grows slowly in culture, producing very little aerial mycelium, but great numbers of white to salmon colored conidia on dextrose potato agar. These conidia are hyaline, one-septate, straight or slightly curved, tapering slightly toward apex. Their size averages $3 \times 12\mu$. They are borne singly at the tips of digitoid condiophores arising usually at right angles to the septate mycelium.

*Sclerotinia disease of sunflower in Manitoba.* G. R. BISBY.

The occurrence of a serious disease of sunflowers cultivated for silage in Manitoba is recorded. The stems are usually, but not always, attacked near the surface of the ground, become brown or black, and soon fall over. Sclerotia are abundantly produced within the stem, and on the outer surface of stems attacked below ground. The disease is well distributed over Manitoba. Certain composite weeds, such as Iva, Canada thistle, sowthistle, and wild sunflowers were found killed in the field by this disease. The results of experiments in progress relative to the fungus, its pathogenicity, and a comparison of this disease with the one described by Lawrence in Washington has been made.

*An important new disease of the cultivated sunflower.* H. E. MORRIS and D. B. SWINGLE.

Cultivated sunflowers are rapidly coming into prominence as a forage crop, especially for silage. In the summer of 1920 a new disease of this crop appeared in several parts of Montana. A fungus that corresponds closely to *Sclerotinia libertiana* Fcl. attacks the roots and crowns causing the plants to wilt and quickly die. The bark about the crown and roots is killed and later is covered with a dense white growth of the fungus. Numerous large sclerotia are produced on the surface of crown and roots, and sometimes in the pith. These are black on the surface and white inside. The fungus does not fruit readily. In the field the disease was first observed on full grown plants, but inoculation of young plants with mycelium of pure cultures causes them to wilt rapidly and die. The disease spreads rapidly in the field apparently by extension of mycelium through the soil. Should this disease attack fields freely when the plants are small very heavy damage is to be expected. In this the first year of its appearance as high as 24 per cent of the plants in one field were killed. Within a month there was an increase of twenty-two per cent.

*Bacterial leaf spot of red clover.* L. R. JONES and MAUDE MILLER WILLIAMSON.

A bacterial leaf spot occurs commonly on the red clovers, both *Trifolium pratense* and *T. medium*, in Wisconsin and apparently widely elsewhere. Leaf spotting appears upon the young leaves in spring and with moist weather progresses upward upon each successive leaf, but is promptly checked by dry heat. Weather similarly conditions its prevalence during summer and autumn. While most characteristic on leaf blades it may attack petiole, stipule, and stem. While not demonstrated it presumably attacks inflorescence and fruit and may thus invade the seed. Apparently it commonly overwinters in the crown or bud and is chiefly disseminated by spattering water. The lesions are intervenous and may be marginal or interior. The spotting begins with minute watersoaked points which blacken as they enlarge. Owing to the limiting influence of the veinlets, they tend to elongate following these and become somewhat angular. The centers may finally dry out, become papery and rupture resulting in ragged shot-holed foliage. Bacterial exudate may occur but is not conspicuous. The organism has been repeatedly isolated since 1916, its characters studied, and its pathogenicity proven. It is a white Bacterium (Pseudomonas) with the group number 222.2323033. The complete description with name proposed for it as a new species has been submitted for publication.

*Septoria leaf blight on the China aster.* W. O. GLOYER.

Certain commercial plantings of the China aster, *Callistephus chinensis*, in New York, have been severely attacked by *Septoria callistephi* n. sp. The disease was first observed in 1915 and again in 1919 and 1920. In unsprayed plantings, all of the plants of some of the suseptible colored varieties were killed. The white varieties appear less attacked and Semple's white branching, while not entirely immune, is resistant. The pycnidia are found in the scurf covering the seed and the disease is spread in the seed bed. The lower leaves are first diseased but later the upper leaves and floral parts are attacked. The tawny colored spots may be isolated but, finally, unite and kill the entire leaf. The plant becomes dwarfed, the size of the flower reduced and the time of blooming is delayed. The pycnidia, 76 to 95 microns in diameter, are observed on either the lower or upper side of the leaf. The straight to flexuous, 3 septate, hyalin spores average 33.5 by 1.5 microns, although varying from 28 to 42 by 1 to 1.5 microns. Wild asters and golden rod, growing but a few feet from the asters, showed no Septoria and, that found

on the chrysantebmum showed pycnidia 190 microns in diameter with 7-septate spores 89 by 3.5 and varying from 54 to 114 by 3.3 to 5.5 microns. The exact control measures have not been fully worked out, although it appears to be amenable to treatment by seed disinfection and spraying with Bordeaux mixture.

*The use of sterilized soils in phytopathological research.* JAMES JOHNSON.

In experiments with pathogens of subterranean parts of plants the limitation of the soil organisms to definite or known forms is fundamental. Special difficulties may arise with sterilized soils where it is desired to prove the pathogenicity of weak parasites, or where certain physiological aspects of parasitism are to be studied. Toxic action either in the form of retarded growth or definite lesions frequently occur which may obscure the actual results. Beneficial action may in a similar way result in misinterpretations. Since individual soils vary widely in their behavior when sterilized by steam, and plant species react very differently to the effects of sterilization, it is important to consider these facts in using sterilized soil in experimental work. It is possible in most instances to avoid these complicating factors by selecting soils which are not toxic when heated, by using host plants which are not sensitive to the the toxic action, or by special treatment to reduce the injurious properties of the soil. Reinfested steam sterilized soils favor infection of host tissue due to the favorable medium offered by such soil for the reproduction of the parasite, but no evidence of modified susceptibility of host plants grown in sterilized soils has been found. As a result of the direct action of sterilized soil on the host plant various types of discolorations and lesions of roots and stems as well as "leaf spots" and "leaf blights" have been produced.

*A constant humidity case.* CHAS. F. HOTTES.

The apparatus to maintain a constant humidity within a variation $\pm$ 1%, consists of a plant chamber 20 $\times$ 20 $\times$ 20 inches constructed of wood with the top and sides of three thicknesses of glass to give two dead air spaces for insulation. This case is furnished with Johnson Service Co., humidostat and thermostat. The case sits on an accurately fitted base three inches in height, through which the supply pipes for the moist and dry air, respectively, pass into the case. The heating elements for the maintenance of a uniform temperature are attached to this base. Between this shallow base and another ten inches in height, is a perforated transite plate through which the shoots are passed into the plant chamber. The roots, in soil or in nutrient solution may be placed under conditions like or unlike those of the shoot, through independent regulation of the temperature, etc., of this lower base. The humidity is controlled by the humidostat making contact, now with one, then with the other terminal of an electro-magnetic valve (Johnson Service Co., old style) that will shift the flow of compressed air (20 lbs.) through the humidifying or the drying apparatus, respectively. The humidifier consists of a ten litre aspirator bottle furnished with an inlet tube tipped with De Vilbiss atomizer No. 28 and partly immersed in distilled water. The air from the valve, passing through the atomizer forms a fine spray and thus becomes rapidly charged with moisture, especially if the water is slightly heated. The air leaves the aspirator bottle through a condenser head and is delivered to the plant chamber by a connecting tube. The drying apparatus consists of a series of calcium chloride towers or a sulphuric acid atomizer (glass) for drying. The regulation is very simple and the range of the instrument is from 20 to 95% relative humidity. When adjusted for medium humidity and without plants in the chamber, the change from moist to dry air and the reverse occurs at intervals of about three minutes. With plants in the chamber the interval on the dry air is lengthened.

*Bacterial leaf spot of lima bean.* W. B. TISDALE and MAUDE MILLER WILLIAMSON.

A heretofore unreported bacterial disease of lima beans has been under observation since 1917 at Madison, Wis. Plants were severely affected during that season in some gardens, but such destructiveness has not been noted since. The disease appears early on the young plants, and observations indicate that the further spread may be checked by dry weather. Leaves, stems and pods are affected. The disease is most conspicuous on the leaves, where it is characterized as reddish-brown spots which later develop grayish centers. Often two or more spots coalesce to form irregular lesions several millimeters in diameter. It appears as reddish-brown streaks of varying lengths on the stems and petioles. On the pods brown spots are produced which extend through the wall and affect the seed coat. Slight water-soaking has been observed on the margins of some spots, and thin crusts of exudate have been noted under field conditions. The method of overwintering has not been determined, but since the seeds are invaded it is very probable that the organism is carried over with the seeds. A white, aerobic, non-gas-forming organism with polar flagella has been isolated from the diseased parts and the etiology determined. Literature contains numerous reports of different organisms attacking legumes, including lima beans, but descriptions indicate that they all differ from the organism under consideration.

*Soybean bacterial blight.* I. V. SHUNK and F. A. WOLF.

A comparison has been made of bacterial blight of soybean as described from Wisconsin (Jour. Agr. Res. 18: No. 4, 1919) and from North Carolina (Phytopath. 10: No. 3, 1920). The diseases differ somewhat in appearance but these differences are of minor importance and it is doubtful if one could differentiate them with certainty in the field. By the use of certain easily operable refinements which consist essentially in adjustment of initial reaction to neutrality and in reducing the hydrolyzation of sugars to negligible quantities, it is determined that the several strains of bacteria pathogenic to soybeans represent two distinct species, *Bact. glycineum* and *Bact. sojae*. They differ principally in that the former produces brown pigment with certain media and forms acid from dextrose, saccharose, lactose, maltose, and glycerine whereas the latter is non-pigment forming and forms acid from the first two of these sugars only. Both organisms have been isolated and proven to be pathogenic in Wisconsin and *Bact. sojae* alone has been found to be associated with soybean blight in North Carolina.

*The relation of soil temperature and other factors to onion smut and infection.* J. C. WALKER and L. R. JONES.

Onion smut offers an especially favorable subject for study of the relation of environment to disease since infection occurs only through the subterranean parts in the early seedling stage. Soil moisture variations inhibit infection only at the very high and very low extremes where germination and growth of the host is also retarded. Soil temperature relations as determined by the Wisconsin soil temperature tank method have marked influence. Onion seeds germinate and growth occurs at soil temperatures of 10° to 31° C. Best top growth occurs at soil temperatures of 20°. Seed smut infection occurs from 10° to 25° C; marked reduction at 27.5 C: complete inhibition at 29° C. Where infection has occurred there is a greater tendency for the seedlings to outgrow the disease at high air and soil temperature (25° C.) than at low temperatures (15° C.); however air temperatures as high as 30°–33° do not entirely prevent smut development provided the soil temperature is kept below 25° C. A series of out-of-doors plantings in inoculated soil, so timed as to expose successive crops of seedlings to gradually increasing temperatures showed that as the soil temperatures rose the

infection percentage fell, with complete inhibition when the mean reached 29° C. These facts have significance in relation to the geographical distribution of the disease. Smut occurs widely in the north where onions are planted in spring in cool soil and is not found in the South where late summer plantings are practiced in warm soils. Temperature records from northern and southern stations accord with the conclusion that soil temperature is a limiting factor.

*A Macrosporium rot of onion.* J. C. WALKER.

An undescribed bulb rot has been noted on white varieties of onions (large bulbs and bottom sets) in Wisconsin and Illinois for the past four seasons. Infection takes place usually at the necks of the topped bulbs, occasionally at other wounds. A semi-watery decay results in which the tissue usually becomes deep yellow to wine red in color due to the pigment produced by the causal fungus. The older decayed tissue eventually becomes dark brown to black due to the development of dark-colored mycelium. Usually one to three outer scales are affected, which in the case of bottom sets results in total loss of infected bulbs. Repeated isolations from diseased bulbs consistently yielded a species of Macrosporium which on potato dextrose agar ordinarily produced an abundance of yellow to red pigment which diffuses throughout the substratum. Sporulation is very sparse in culture but can be induced by wounding the mycelium as described by Kunkel and by Rands for *Macrosporium solani*. The disease was readily produced by inoculation of healthy bulbs.

*The occurrence of dodder on onions.* J. C. WALKER.

Three instances of dodder (*Cuscuta* sp.) attacking the tops of onions have been noted: (1) at Stockton, Calif., in 1919, (2) at Racine, Wis., in 1920, and (3) at Lansing, Ill., in 1920. The first two instances were on the large bulb crop and little damage was done. In the last, however, the parasite has caused considerable damage to onion sets. In a field of ¼ to ½ acre examined shortly before harvest, thirteen oblong patches were found varying in size from 4 × 6 to 15 × 21 feet. In the centers of the largest patches the tops of the plants had been completely killed and the bulbs were much reduced in size. The dodder appeared in one or two centers when the onions were about two inches high. From these it had been spread by weeders and cultivating implements to other parts of the field. Unless care is taken by onion set growers to eradicate this parasite early in the season, it may prove to be a serious pest, especially under the prevailing methods of culture in which the plants are grown under extremely crowded conditions and continuous cropping is commonly practiced.

*Seed transmission and overwintering of cabbage black rot.* JOHN MONTEITH, JR.

Frequent observations in Wisconsin have shown black rot to be more severe in fields from imported than from home grown seed. Experiments showing definitely the method of overwintering and the relation of climatic factors to the early development of the disease are lacking. An attempt is being made to clear up these points. The disease persists in overwintered seed heads. However, our experience with one such plant showed that it failed to mature seed but might serve as a center of infection. The organism probably lodges on the seed coats during threshing and is carried over to the next season in this manner or possibly within the seed from systemic or pod infection. Clean seed, sown in sterilized soil mixed with diseased cabbage leaves which had been exposed to a Wisconsin winter, yielded seedlings with a high percentage of infection. Artificially inoculated seeds, allowed to dry three days and planted in

sterilized soil, yielded seedlings with a large percentage of cotyledon infection. Subsequent progress under greenhouse conditions was slow, however, the disease seldom appearing on the first true leaves in less than eight weeks after planting. Evidence points to climatic factors during seed bed growth as important in determining the rapidity of spread in the seed bed from primary centers and consequently the severity of epiphytotics.

*Greenhouse propagation of cabbage resistant to yellows.* J. C. GILMAN and A. T. ERWIN

A method for developing strains of cabbage resistant to yellows in the greenhouse has been devised for use in the case of early cabbage which cannot be stored satisfactorily. The seed was planted in flats of soil infested with *Fusarium conglutinans* and subjected to the optimum temperature for the development of the disease. The selections were made about a month later, the healthy seedlings being transferred to pots and later to a garden bed in the greenhouse. The plants came into flower late in March and produced abundant seed. This method has been used successfully for three years. Seed from these plants showed resistance in the field in both 1919 and 1920. The relative resistance from the plants selected was as follows:

| | 1919 | | 1920 | |
|---|---|---|---|---|
| | NO. PLANTS | PER CENT YELLOWS | NO. PLANTS | PER CENT YELLOWS |
| Best strain | 73 | 23.3 | 27 | 0 |
| Average of selected strains | 540 | 25.5 | 2531 | 22.0 |
| Commercial seed | 646 | 61.3 | 897 | 63.7 |

The merits of these resistant strains as to type and earliness have to be determined in the field.

*Bremia on hothouse lettuce.* I. E. MELHUS.

Under Iowa conditions *Bremia lactucae* has caused serious losses to the greenhouse lettuce crop. It is most rampant on plants in the seedling stage. This organism like some species of Cystopus and Phytophthora flourishes only at low temperatures and in an atmosphere of very high humidity. The optimum temperature for its spore germination is from 6 to 10° C. a temperature which prevails in the lettuce houses during the winter and spring months. The wild species of Lactuca: *L. scariola* var. *integrata*, *L. canadensis*, *L. sagittifolia* and *L. ludoviciana* are common as foul weeds about compost piles, vacant lots and fence corners. All of the above species are readily infected with *Bremia lactucae* occurring on cultivated lettuce and vica versa. The downy mildrew probably spreads from the wild to the cultivated lettuce. In this latitude the wild species of Lactuca are winter annuals and may serve as means for carrying the organism over from one season to the next in the vegetative stage. Although very frequent search has been made for oospores in cultivated lettuce plants, none have been found. Bremia is able to survive in hot house soil from one year to another, providing it is not allowed to freeze. The control of this disease has been effected by spraying the lettuce seedlings with Bordeaux mixture (4–4–50) two or three times before they are transplanted.

*Celery yellows.* G. H. COONS and RAY NELSON.

The stunting disease of celery first discovered at Kalamazoo, Mich., in 1914, as a serious disease of the Golden Self Blanching variety has increased in extent so that

practically all soil in the immediate vicinity of that city is no longer capable of producing this particular variety. The disease is also known from all other extensive celery districts in the state. It is also a serious disease in New Jersey, Indiana, Massachusetts and Connecticut. Although first suspected as being of bacterial origin, and reported by other observers as due to the joint action of bacteria and Fusarium, definite proof is now available for assigning to a new species of Fusarium the causal relationship of this disease for which the name Celery Yellows is proposed. The variety Easy Bleaching and all of the so-called green varieties are tolerant to this disease. In the golden varieties excessive stunting occurs, accompanied by yellowing and thickening of the foliage, together with reddening of the vascular system.

*Recent studies on bacteriosis of celery.* R. F. POOLE.

Celery rots, due to a bacterium, have been severe for a number of years in New Jersey. Greatest losses occurring where Golden Self Blanching varieties are grown on muck soils. The green varieties, previously considered as being immune to the bacterium, were found to be slightly susceptible to the organism. When Golden Self Blanching varieties are planted in muck soils not later than May 15th a good crop is usually produced; temperature at this time not being favorable for the development of the organism. "Heart rot," "foot rot," "leaf blight," and "browning of young roots" are the principal symptoms of decay. Repeated isolations and inoculation experiments have proven that all these are due to the same organism. With the exception of a few minor cultural growths, this soft rot Bacillus conforms to the descriptions of *Bacillus carotovorus* (Jones) and of *Bacillus apivorus* (Wormald). These are probably different strains of the same organisms. Inoculations made with this organism in a partly saturated atmosphere and at temperatures ranging from twenty-five to thirty-five degrees Centigrade have produced soft rots on the green varieties of celery in twenty-four hours. Plants inoculated under normal conditions and allowed to dry rapidly gave negative results.

*Bacterial spot of tomato.* MAX W. GARDNER and JAMES B. KENDRICK.

Bacterial spot is a typical spot disease of the fruit, leaves and stems of tomatoes in Indiana and nearby states. Raised, black, scab-like lesions with watersoaked borders are produced on the fruit. The centers of these lesions may later become sunken. Because of the fruit spots this disease is extremely objectionable to market gardeners and canners. Leaf lesions are black and greasy with parchment-like centers which tend to crack. The causal organism is being described as a new species of bacteria. It is highly sensitive to acidity in culture. Leaf infection is stomatal, while fruit infection has been secured only through wounds such as needle punctures. Ripe fruits are immune probably because of their high H-ion concentration. Forty-one varieties of tomatoes have been found susceptible and no resistant varieties have been found. The causal bacteria have survived eight months desiccation on tomato seed. Inoculated seed has yielded diseased seedlings with characteristic primary cotyledon lesions and commercial seed saved from fruit grown in a badly infested field yielded about 1% of infected seedlings when planted in sterilized soil. The organism is carried over winter on the seed. Seed disinfection in mercuric chloride, 1:3000, for five minutes has been found safe and effective and is recommended as a control measure.

*A phytopthora crown rot of rhubarb.* W. S. BEACH.

An investigation of a crown rot of rhubarb prevalent in Philadelphia County, Pa., has revealed in the discolored tissues of the buds, the petiole bases, and the roots the

constant presence of a gnarled, coenocytic mycelium that is chiefly intracellular. The culture of this mycelium proved it to be that of an undescribed species of Phytophthora. Conidia and oospores are abundantly produced on lima bean agar, but these structures have not been observed on host material from the field. In preliminary inoculation experiments pure cultures of the fungus were pathogenic on vigorous petioles of large rhubarb plants and on seedlings of moderate size. Diseased tissues turn dark brown, but may not soften or break down.

The disease becomes severe during wet weather in late summer, and has caused the sudden death of considerable areas in rhubarb fields, usually in those recently set, having poor drainage, or receiving heavy manuring. Colletotrichum on the petioles is much more severe on plants affected with crown rot. Numerous other fungi found to be saprophytic complete the decay of the dying or weakened plants, but with the return of dry weather many plants recover in part.

*Studies in parasitism in the Fusarium group.* H. C. YOUNG and C. W. BENNETT.

Experiments with *Fusarium oxysporium* have confirmed the view that wilting of potato plants when attacked by this fungus is not due to a mechanical plugging of vascular tubes, but is due to certain products of the fungus acting on the host tissue. Wilting can be produced by a water solution of alcoholic precipitate derived from 28 day cultures in Richard's solution. The exact nature and chemical composition of the substance or substances responsible for wilting are being investigated.

*The pathogenicity of Corticium vagum as affected by soil temperature.* B. L. RICHARDS.

Studies conducted during the seasons 1918–1919 in Wisconsin, both in the field and under controlled conditions in the greenhouse, have shown that the temperature of the soil is a vital factor in determining the degree to which the potato and other crops may be damaged by *Corticium vagum* B. & C. (*Rhizoctonia solani* Kühn). The fungus may produce lesions on the underground stems of the potato plant in soils ranging in temperature from 9° to 29° C. Severe damage to this plant, however, is limited to soil temperatures below 24° C. with an optimum for tissue destruction between 15° and 21° C. Destruction of the growing points of the young shoots does not occur at soil temperatures above 21° C. This feature of the disease is clearly correlated with the rate of growth of the primordia. Experiments with the potato, the pea, and the bean indicate that the temperature requirements for the pathogenic action of the fungus on these hosts is determined by a fixed physiological character of the fungus, and is but slightly influenced by the temperature relations of the hosts, or by the species of plants on which the parasitic relation becomes established. No definite correlation was found to exist between the optimum temperature for the growth of the fungus in artificial culture and that found most favorable for its maximum parasitic action.

*Tip-burn and the leafhopper.* G. P. BURNS.

The remarkable paper recently reported which tended to show that tip-burn in the potato was due to the leafhopper because plants protected by a wire cage with meshes small enough to exclude the beetle were not affected, caused the writer to investigate the effect of such screens upon other factors of the habitat, such as solar radiation, wind velocity, humidity of the air, evaporation etc. and also on the rate of transpiration of coniferous and broad-leaved plants. The results show that in addition to excluding the beetle the wire cage exerted a profound effect upon all the factors of the habitat and greatly decreased the amount of water transpired. Some of these results were as follows:

| | OPEN FIELD | UNDER WIRE SCREEN |
|---|---|---|
| Solar radiation | 100% | 49.9% |
| Wind velocity | 100% | 7.8% |
| Evaporation | | |
| White atometer | 100% | 60.0% |
| White lack atomemeter | 100% | 54.8% |
| Light Intensity | | |
| Clements Photo | 100% | 43.0% |
| Humidity | 100% | 105.0% |
| Temperature | 100% | 106.0% |
| Transpiration | | |
| White pine | 100% | 66.6% |
| Norway spruce | 100% | 84.2% |
| Hydrangea | 100% | 73.0% |

These results would seem to indicate that we should use the greatest caution in assigning causes of physiological phenomena.

*Second report on the reaction of American potato varieties to the wart disease.* FREEMAN WEISS and C. R. ORTON.

Test of American potato varieties for reaction to the potato wart disease begun in 1919 were continued during 1920 at Freeland, Pa., and at Thomas, W. Va. Forty-three varieties, in addition to those tested last year, were grown this year, of which 17 appear to be immune. Twenty-one selected seedlings developed by the U. S. Department of Agriculture were tested and 5 proved to be immune. To date, 78 named varieties of American origin have been tested. Of these, 27 are immune. Of 51 seedlings from the Department of Agriculture 12 are immune. The designation immune is used advisedly, as these varieties do not become infected at all, even when grown in soil in which non-immune varieties are readily and severely attacked. The 17 varieties and seedlings reported as immune in 1919 have fully justified this title in the 1920 tests both in the Pennsylvania and West Virginia tests. Similarly, foreign immune varieties remain entirely free from infection when in this country. The list of American immune varieties now includes Irish Cobbler, Flourball, First Early, Early Eureka, Early Petoskey and New Early Standard of the Cobbler group; Ehnola, Extra Early Sunlight, White Albino and Early Harvest of the Early Michigan group; Spaulding Rose, Northern King and White Rose of the Rose group; Burbank, of the Burbank group; Green Mountain, Green Mountain Junior, McKinley, New Oregon, McGregor, Norcross and Gold Coin of the Green Mountain group; Round Pink Eye and McCormick of the Peachblow group; and Keeper, Success and Ursus, which are unclassified.

*Catalase, hydrogen-ion concentration and growth in the potato wart disease.* FREEMAN WEISS and R. B. HARVEY.

A study was made of H + concentration and catalase activity in the overgrowths of the tubers of Irish potatoes caused by infection by *Chrysophlyctis endobiotica.* The H + concentration of wart tissue is constantly greater than that of healthy tubers from the same plant, the values being represented by pH6.00 and pH6.49 respectively. Catalase activity is much greater in the wart tissue, the values being represented by 17.9 for diseased and 7.8 for the healthy tissue. Catalase activity is strongly correlated with growth in spite of the higher acidity of the proliferation. This differs from other types of plant overgrowths previously studied in which diminished acidity is correlated with increased catalase and growth activity.

*The present status of the potato wart in Pennsylvania.* W. A. MCCUBBIN.

Surveys for wart in 1920 and previous years by federal and state agencies, together with additional scouting planned for 1921, will practically complete the preliminary efforts to locate the disease in all suspicious areas. In any permanent policy for locating further outbreaks, scouting must be supplemented by publicity methods to arouse widespread public interest. Potato wart has now been found in 53 towns and villages in 9 counties in Pennsylvania. 781 gardens are known to be infested in these places. The actual area of these gardens is less than 100 acres, though the infection centers are scattered about in two general districts which together involve some 3000 square miles of territory.

The Pennsylvania state quarantine aims to prevent all movement of infectious material, particularly potatoes and manure, from the areas under quarantine, and to replace, as rapidly as possible, susceptible potato stocks with immune varieties, not only in the quarantine area itself, but in a "safety zone" about it. Seed of immune varieties is grown under supervision and then tagged and distributed under seal.

In the quarantine area potatoes can be grown only under permit, which plan facilitates the detection in summer of all plants of susceptible varieties accidentally or inintentionally introduced.

*Inoculated vs. uninoculated sulfur for the control of common scab of potatoes.* WILLIAM H. MARTIN

The work with sulfur for the control of scab has been continued this year, the scope of the work being broadened to include tests of inoculated and uninoculated sulfur. Inoculation was effected by mixing the commercial sulfur flour with one per cent of soil from a compost heap known to be well supplied with sulfofying organisms.

Soil samples were taken before the sulfur applications were made and again at digging time. The hydrogen-ion concentration of water extracts of the soil samples was determined colorimetrically. The inoculated sulfur brought about greater decreases in exponent values than the uninoculated sulfur and with each decrease below that of the check plots there was a corresponding decrease in the per cent, of scabby tubers. While only a few experiments were conducted with the inoculated sulfur its advantages over the uninoculated were rather definitely established.

*Inoculated sulphur for potato scab control.* R. E. VAUGHAN.

The use of inoculated sulphur, "Bac-sul" for the control of potato scab in Wisconsin, 1920, was not successful. Bac-sul was applied at the rate of 400 pounds to the acre when the plants were breaking ground. In one experiment, 35 per cent showed scab where treatment was used, with 37 per cent scab in the check. In another experiment on heavier soil, the scab in the treated lot was slightly over half and in the check rows slightly less than half. The slight variations in the amount of scab could easily be accounted for by the natural variation in amount of soil infection. The season was very dry from the time the sulphur was applied until harvest.

*Testing seed potatoes for mosaic and leaf-roll.* F. M. BLODGETT and KARL FERNOW

Attempts were made to eliminate potato mosaic and leaf-roll from small lots of seed for seed plots (1) by growing one tuber from each hill as an index to the entire hill, and (2) by growing one eye from each tuber as an index to the remainder of the tuber. In several lots of hill units, only single stalk hills were selected as it was thought that these might behave more uniformly as to disease than hills with a number of stalks. This did not appear to be the case. In the limited number of tests made, there was

nearly as large a percentage of mixed hill units, part mosaic and part healthy, in the progeny of single stalked hills as in hills with a number of stalks. Only small decreases in the percentage of mosaic were obtained by sorting out the hills labelled mosaic on the basis of the greenhouse test of one tuber from each hill. Considerable reduction in the percentage of mosaic was secured, however, by sorting on the basis of an eye test of individual tubers. By this method in two tests a reduction from a percentage of about 27 to 1 was secured and in a third test from 65 to 33.

*Cooperative seed treatment using hot formaldehyde.* R. H. PORTER

This method has been successful under Iowa conditions in treating a large quantity of potatoes in a short time and is suited to community cooperative effort. Creameries or steam engines are practicable as a source of heat. Farmers organize their own seed treatment centers. In one case over 530 bushels were treated in less than six hours.

Treated and untreated seed planted in the same field have shown a decided advantage in favor of the treated seed. In four fields which were planted with treated seed in 1919, and averaging about 8 acres in size, 15 per cent of the tubers were infected with scab. The untreated seed in each case was planted in the same field but usually consisted of 4 to 10 rows. These plots showed 76 per cent scab.

In 1920 four fields planted with treated seed and averaging about 5 acres showed 33 per cent of the tubers infected with scab as compared with 68 per cent in the four plots planted with untreated seed. The basis of percentage determination used was the number of infected tubers out of the total yield of equal areas. A single scab sorus was sufficient to place a tuber in the infected class.

The control of Rhizoctonia was as follows: Four plots in 1920 planted with treated seed gave an average by weight of 11.1 per cent infection as compared to 35.4 per cent in the plots planted with untreated seed.

*Cooperative potato seed treatment experiments.* (Committee Report). I. E. MELHUS

Cooperative potato seed treatment experiments for the control of *Rhizoctonia solani*, were carried out by the Iowa, Wisconsin and Minnesota Experiment Stations in 1919 and the Iowa and Wisconsin Stations in 1920. Solution of formaldehyde (1–240) cold for two hours, formaldehyde (1–120) 50°C for 2 minutes, copper sulphate (3–4000) for 2 hours, and mercuric chloride (1–1000) for one and one-half hours were tested comparatively. Seed was treated in the various ways by each station and then divided so that each station had plots of the various treatments of their own and the other two station's seed.

The Minnesota seed at Minnesota showed that copper sulphate gave less control than hot formaldehyde, but the reverse was true of these same treatments under Iowa conditions. The mercuric chloride gave better control of the disease than the copper sulphate, but not as good as the hot formaldehyde at Minnesota but was poorer than either at Iowa. At Wisconsin the mercuric chloride and the hot formaldehyde were about equally efficient, the copper sulphate giving the poorest results. Double strength formaldehyde at 8°C for 2 hours gave fair control at all three stations.

The Wisconsin seed was planted at but two stations, Iowa and Wisconsin. At Wisconsin mercuric chloride for 1½ and 2 hours gave the best control, while formaldehyde gave practically none, At Iowa the hot formaldehyde equalled the mercuric chloride for 1 hour. Although it was not as good as the 1½ and 2 hour treatment with the solution.

The Iowa seed at Minnesota showed good control of the disease with both the hot formaldehyde and the mercuric chloride, although the former was slightly better here and also at Iowa. The reverse was true at Wisconsin.

In 1920 Iowa and Wisconsin alone cooperated. Wisconsin seed at Wisconsin showed excellent control with mercuric chloride and practically none with formaldehyde hot or cold. At Iowa cold formaldehyde showed the best results, hot formaldehyde the second and mercuric chloride third. Copper sulphate was ineffective at either station.

Iowa seed at Wisconsin showed best control with mercuric chloride, second with cold formaldehyde and poorest with hot formaldehyde. At Iowa hot formaldehyde was best. Again copper sulphate was ineffective.

*The cooperative potato spraying project.* (Committee Report). G. R. BISBY.

During 1918, 1919, and 1920, the need for further knowledge regarding the effect of field applications of Bordeaux mixture to potatoes in certain regions of North America was brought to the attention of workers in the various states and in Canada. The preliminary questionaire in 1918 resulted in a general response giving the status of the problem in various states, and some new data. A definite project was drawn up for 1919, and submitted to workers who might be interested. The problem was again brought before many pathologists in 1920 with the suggestion that the cooperation of entomologists would be valuable.

Cooperators have been able to add much to the knowledge for certain regions regarding the value of spraying and the schedule advisable, etc. There are still, however, large areas in North America where information is lacking, or results are uncertain. The results obtained, the methods employed, and the future possibilities of this project should be discussed.

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PHYTOPATHOLOGY

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# THE BACTERIAL BLIGHT OF THE BEAN: A SYSTEMIC DISEASE

WALTER H. BURKHOLDER

The bacterial blight or bacteriosis is a common and widely distributed disease of the bean. Although at one time it was thought to cause but little damage, it has increased in importance in the last few years until now it is one of the serious diseases of the crop. The U. S. Plant Disease Bulletin for 1919 shows that during that year the bacterial blight was present in all the important bean-producing districts in the United States, causing an estimated loss of from 3 to 8 per cent of the crop in the states listed. In New York State, during the last three years, the disease has been found by field surveys to be of greater importance than the anthracnose.

The cause of the bacterial blight is well known from the classical work of Erwin F. Smith (8, 9), who studied and named the organism *Bacterium phaseoli*. Notwithstanding this work of Smith and the work of of Edgerton and Moreland (2), Muncie (5, 6), and others, there are many phases of the disease that are not well understood. The writer has been making a study of the disease as it occurs in New York State, and while the work is by no means completed, certain facts of such outstanding importance have been determined that it seems worth while to present them at this time. It is believed that the systemic nature of the bacterial blight, evidence of which will be presented, accounts in a large measure for the various anomalies met with in this disease. Unlike many of the parasitic plant diseases there are different symptoms depending upon a variety of conditions not clearly understood.

## USUAL SYMPTOMS

In general the bacterial blight is thought to be a leaf and pod disease. It is on these parts of the bean plant that the most striking evidence

of the disease occurs. On the leaves the lesions first appear as small, water-soaked or light green, wilted areas. As the spots develop the tissue becomes dry and brittle with a yellow border, surrounding which there is frequently a paler green zone. One or more of these lesions may increase in size and involve a large part of the leaflet. No other disease of the bean produces on the leaf as large a necrotic lesion as does the blight; consequently this symptom is seldom confused with that of any other disease. In epiphytotics of the bacterial blight the foliage of most of the plants in a field may be affected, and from this, together with the whipping of the wind and rain, a very ragged appearance results.

The bacterial blight causes small, water-soaked spots on the pods, which gradually enlarge to irregular blotches. A yellowish-white incrustation, due to the bacteria oozing out in large masses and drying, frequently covers these spots. As the lesions become older, the tissue involved loses its water-soaked appearance and becomes dry and sunken. The color of the spots is often a brick red and later assumes a brownish tinge.

The bacteria on the pods readily work their way through the tissue and infect the bean seed. If infection takes place when the pods are young and tender, the seeds may rot entirely, or become so severely injured that there appears to be nothing left but the shriveled seed-coat. On the other hand, the bacteria may cause on the bean seeds only slight spots, in many cases similar to those produced by the anthracnose fungus. On white seeds the blight lesions are yellow and, when covering a considerable area, frequently varnish-like. When *Bacterium phaseoli* once gains entrance into the seed it persists over winter, and various attempts to kill it by seed treatment have been unsuccessful. In New York State, Red Kidney seeds two years old have been found to harbor viable bacteria, and in several cases seeds three years old when planted have produced blighted plants. This is contrary to the report of Rapp (7) from Oklahoma, who states that the blight organism is found to be dead in bean seeds two and three years old.

On the stem of affected bean plants various types of lesions have been observed to occur. In the seedling stage these lesions appear as small, water-soaked areas similar in appearance to those found on the pods. They may be distinguished from the anthracnose spots, as they are never so deep in the tissue, nor so dark in color. On the older plants the lesions appear as reddish dashes extending longitudinally with the stem. In these spots the tissue frequently is somewhat raised on the surface and split. The lesions on the stalks causing

the most damage to the plant have been referred to by the writer (1) and Muncie (5) as stem girdle. In this case the bacteria attack the stalk at the cotyledon node, or less frequently at the various other nodes higher up the plant. A red necrotic lesion is formed, which greatly weakens the stem and causes it to be toppled over very easily during a brisk wind. Fields have been observed by the writer where during a storm nearly 5 per cent of the plants were blown over in this manner. The varieties Red Kidney and Refugee appear to be very susceptible to this form of the disease.

### UNUSUAL SYMPTOMS

Besides these more or less common symptoms occurring on the bean plant, a number of other manifestations of the bacterial blight may be found. Certain of these are fairly common in the bean fields of New York State, but since in some cases they occur on seedlings, they have been overlooked. The blight is never severe epiphytotically until near the maturity of the plants. In the early stages of growth of the host, however, certain lesions are present, the bacteria causing which act as sources of infection for the later spread of the pathogene. From all observations, these lesions arise from infection of the cotyledons due to the planting of blight-infected seeds. Possibly one of the earliest symptoms to be noticed is the appearance of the so-called "snake-heads," a name applied to the young seedlings when the growing tip of the plant has been destroyed and only the cotyledons remain. At times the snake-heads are able to send forth new shoots, but they seldom produce a large number of pods. Such injury has been attributed by Hawley (3) to the seed-corn maggot (*Phorbia fusiceps* Zet.) which is undoubtedly the cause in the majority of cases. On the other hand, in the spring of 1919 a great many injured seedlings were found on which no attacks of the maggots were in evidence. In many such instances bacteria were associated with the injury. The bacteria when isolated and used for inoculations produced a blighted condition in the bean plant, and were to all appearances *Bacterium phaseoli*. Moreover, on January 21, 1919, fifty White Marrow bean seeds showing blight lesions near the plumule end were planted in flats in the greenhouse. Ten of these produced typical snakeheads. Other experiments in which blight-infected seeds have been used have given varying percentages of seedlings with similar injury. It should be stated here that the writer also has seen *Thielavia basicola* Zopf and Rhizoctonia cause this injury to the young seedlings. In these cases the fungus was always in evidence.

Macroscopically it is impossible to determine with certainty the lesions on the cotyledons due to the blight bacteria. Many other organisms, both pathogenes and saprophytes, may cause like spots, in most cases all being a brownish color. Peculiar lesions, however, are produced on the primary leaves by *Bacterium phaseoli*. Here the leaf is marked as a mosaic, with small, angular, water-soaked areas over the surface. This is due to the infection of the islet tissue between the veins. Such lesions frequently do not develop, and the plant appears to throw off the disease. At other times the disease may appear on the young leaves as spots similar to those on the older leaves. After inoculating six small seedlings, February 27, 1920, in the greenhouse, by spraying the leaves with a water suspension of *Bacterium phaseoli*, the mosaic-like lesions were produced in all cases. The incubation period was five days. Later the spots on several of the leaves enlarged to the other type of lesion.

Another sympton of the bacterial blight that occurs in the seedling stage is the wilt. Occasionally this symptom may be observed in the field, and more frequently in the greenhouse where blight-infected seeds have been planted. A slight flagging of the leaves usually takes place, followed shortly by a drooping and general wilting. The stalk in most cases remains upright. On some seedlings one leaf will wilt before the other. In conducting inoculation experiments to determine the ability of *Bacterium phaseoli* to cause a seedling wilt, this one-sided wilting of the plant occurred in the majority of the cases. Such an uneven progress of the disease is due, no doubt, to the bacteria becoming established on one side of the plant only. It should be stated also that only a small percentage of the inoculations produced seedling wilt. Infections, however, frequently appear in the later development of the host plant, showing that external conditions governing the seedling wilt are not understood.

From the preceding paragraph it might be concluded that wilt is to be found only in the seedling stage. Such an assumption, however, is not true. In New York State during the last few years the wilting symptom of the blight occurred very generally in the White Marrow bean fields, especially after the pods had set. In some instances the entire plant died, while in others only a portion of the plant showed the disease. In the latter case, however, the wilting frequently spread until it involved the whole bean plant. The wilting symptom of the bacterial blight is one of the evidences of the systemic nature of the disease, and is treated below in more detail.

SYSTEMIC INVASION

During August of 1918, while examining several fields of White Marrow and Red Marrow beans in western New York, the writer found a number of apparently healthy plants producing blighted and water-soaked seeds. Further inspection of these bean plants showed that they were somewhat dwarfed, and a microscopic study revealed the fact that the vascular systems of the stalks were invaded by bacteria. No external lesions occurred on the leaves and pods. Since the bacterial blight caused by *Bacterium phaseoli* was found present in the field, it was considered probable that the blighted seeds were caused by this disease. Furthermore, about harvest time, clean appearing pods were found containing seeds with typical bacterial blight spots on them. Other parts of the plants also showed traces of the disease. Careful examination of these seeds revealed yellowish discolorations on the hilum, which indicated that the pathogene had entered the pod through the vascular system. Later, inoculation experiments conducted on bean plants with the bacteria isolated from individuals with infected vascular systems gave spots on the leaves and pods typical of the bacterial blight.

During the summer of 1919, careful observations were made of the development of the blight in the bean fields, and by these, together with inoculation experiments, the following points in the life-history of the pathogene were determined. From the primary infection of the cotyledons the bacteria readily gain entrance into the vascular system of the bean plant. The seedling wilt is a result of the behavior of the pathogene at this time. Due to some conditions not understood, bacteria rapidly increase, fill the xylem vessels, and a wilt soon follows. Upon microscopic examination the organisms will be found in great masses in the xylem vessels extending up the stem from the cotyledon node to the leaves. They also may be found extending down the stem about an inch below the cotyledons. In severe cases bacteria break through the walls of the vessels and spread into the nearby parenchymatous cells. That the pathogene causing seedling wilt may enter the stem from infected primary leaves as well as from the cotyledons seems probable, since in a number of cases the bacteria do not extend down the stem to the cotyledons. It should be stated here that the mosaic-like mottling of the primary leaves is due to the infection of the palisade cells and the mesophyl tissue, while the larger leaf spots, considered more typical of the blight, are caused primarily by the pathogene in the leaf veins. In the latter case the parenchymatous cells may be involved, but the rapid development of the lesion is due to the pathogene traveling in the xylem.

Due to some conditions not sufficiently understood, the bacteria at times enter the vascular system of the stem without causing a wilting of the young plant. Here the organism persists, causing a dwarfing of the plant, and on days of high evaporation producing an incipient wilting. Furthermore, on such plants a burning of the tips of the leaves has been observed to occur without the accompanying presence of the bacteria in the leaf. This last symptom undoubtedly is caused by the presence of the pathogene in great masses, plugging up the vessels and disturbing the transpiration of the plant. The White Marrow bean plant, which has an indeterminate habit of growth, fails to vine under such conditions. Few pods are formed, and the affected plants are dwarfed and mature earlier than the normal individuals. Such plants resemble somewhat those infected with the root-rot organism, *Fusarium martii phaseoli*. Consequently, without careful examination the two diseases may be confused.

*Bacterium phaseoli* infecting the vascular system of the host plant may behave differently under unlike conditions and in the different varieties of beans. In many instances, no external lesions or death of the plant parts occur until blossoming time, or even after the pods have set. The entire plant may wilt with the leaves and pods persisting on the plant, as frequently happens in the case of the White Marrow variety of beans. In the pea and kidney varieties, the leaves may fall and leave the clean, unspotted pods exposed.

Besides the wilting just described, other symptoms from the systemic infection occur on the plant. The bacteria may break through the xylem vessels and cause lesions to be produced on the leaves similar to those caused by local infection. First the tip or some other portion of the leaf wilts and later becomes dry and brown. These dead areas finally involve the entire leaf. On the stem the bacteria break through, producing reddish necrotic lesions. These appear as streaks that extend longitudinally with the branch or petiole on which they occur. At other times the lesions may not break through the surface, but remain as reddish-brown discolorations beneath the epidermis. From careful examination of the stem girdle, it appears that it also arises in some cases from the bacteria in the vascular system.

In the vascular infected plants the bacteria often extend not only throughout the parts above ground, but also into the root system. Here in the xylem vessels of the tap and lateral roots, great masses of the organism may be found as in the portion of the plant above ground. No external lesions, however, have been observed to be produced by the pathogene below ground.

One of the most important points in the behavior of the blight bacterium is its ability to enter the pods through the vascular system and infect the seeds without causing lesions on the surface of the pods. In entering the seeds through the vascular system, the pathogene frequently causes only a small, yellow discoloration at the hilum. This sign of the disease in colored seeds is not readily detected. In white seeds also, where normally there is a slight yellow marking about the hilum, the infection may be overlooked. Severe infection, however, produces on the seed-coat the yellow blotches so characteristic of the blight disease. This method of infecting the seeds without producing lesions on the pods is of considerable importance from the control standpoint. It immediately becomes evident that control cannot be accomplished through the selection of healthy pods. Such a plan has been recommended for the bacterial blight, since it proved successful in controlling the anthracnose disease. With the anthracnose, however, all infections are local. To be certain of securing bean seed free from the bacterial blight, healthy plants only should be selected.

It is very probable that in a large majority of cases the hilum-infected seeds carry the bacteria over winter. It is difficult for shriveled or undersized seeds or those with discolored spots on them to pass through a modern bean seed house, as such seeds are carefully gleaned by machinery or by the pickers. Many of the hilum-infected seeds appear normal in size, and only the slight yellow spot reveals the infection. Such seeds on planting may produce diseased plants.

This systemic infection of the bean plant by *Bacterium phaseoli* occurs, no doubt, wherever the disease is found. In New York State it has been observed frequently during the last two years. Jones (4) gives plates and descriptions which indicate that it is found in Ontario, Canada. Barss, in a conversation with the writer, stated that such plants occur in the bean sections of the Pacific Coast. This condition, however, may be overlooked readily, which doubtless accounts for its not having been emphasized before.

In the bean sections of New York State it is not this type of infection, however, that causes the greatest damage. Plants showing systemic infection occurring from the seed are, as a rule, in the minority. They do serve, nevertheless, as sources of inoculum for the epiphytotics of this disease that appear in August. In the fields, up to blossoming time, the bacterial blight is seldom an important factor, and is rarely noted. During the hot month of August, however, it frequently breaks forth. Possibly the temperature has some bearing on its severity at this time of the season. The mature leaves, too, readily become infected. The blight under these conditions spreads very rapidly over

a planting. Rain and insects appear to aid in the dissemination of the pathogene. Among the dry shell beans, the kidney varieties become more severely infected than either the pea or marrow varieties. A number of the garden varieties appear to be even more susceptible than the kidney.

## EXPERIMENTAL WORK

A number of inoculation experiments have been conducted from time to time to determine the various points brought out in the preceding account. Some of the more typical ones are here recorded. On May 21, 1919, twenty-one White Marrow and Red Kidney plants about three weeks old were inoculated by injecting into the plants at the point of cotyledon attachment a water suspension of *Bacterium phaseoli*. In doing this a hypodermic needle was used and the stem pierced so that the vascular system was broken at one point. The inoculated plants were kept in a moist chamber for several days, after which they were placed in the greenhouse, where the temperature is usually high at that time of the year. The bacteria used in the experiment were isolated from a blighted White Marrow plant that had been grown in the greenhouse from an infected seed. After a week's time, symptoms of the disease began to appear, and within two weeks sixteen of the plants showed blight lesions, which in most cases were on the side of the plant where inoculations had been made. In all instances one or more of the leaves on a plant showed signs of spotting and wilting. The presence of bacteria was also discovered in the xylem and could be traced from lesion to inoculation court. This one of several similar experiments shows the ability of *Bacterium phaseoli* to travel through the vascular system from the cotyledon node to the leaves of a bean plant, and there produce lesions.

A further experiment to prove the systemic nature of the bacterial blight and also the ability of the hilum-infected seeds to produce blighted plants was conducted. On January 23, 1920, fifty Wells Red Kidney bean seeds that showed discolorations on the hilum but otherwise appeared normal were planted. The field from which the seeds had been secured had been severely infected with the blight, so that it was thought a large percentage of the discolored hila were due to *Bacterium phaseoli*. Only thirty-eight of the seeds germinated, but all of these grew past the seedling stage without any visible signs of the disease. By February 27, however, twelve of the plants showed symptoms of the bacterial blight. Four had wilted entirely. On the other eight the leaves flagged and died from time to time, and the bacteria in several cases broke out on the stem. On examining the infected plants the xylem

vessels were found to be filled with bacteria. The cells about the vessels had become infected also. On February 27, the stem of one of the plants was broken open and placed in a small amount of water, the bacteria being allowed to ooze out. This water was then sprayed over five Marrow bean plants, which were placed in a moist chamber for two days and then left in a greenhouse kept at a temperature of about 26° C. Five days later there appeared on the leaves of the inoculated plants small, water-soaked spots, which in about two weeks developed into the larger and more typical blight lesions.

When inoculation experiments were conducted with bacteria taken from pure cultures, negative results were very frequently obtained. It is thought that *Bacterium phaseoli* probably loses its virulence very rapidly in culture. In making inoculations with the organism from infected plants good infection resulted in the majority of cases.

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# THE INCREASE IN RESISTANCE TO CITRUS CANKER WITH THE ADVANCE IN MATURITY OF CITRUS TREES

H. Atherton Lee[1]

The present paper advances the hypothesis that as citrus trees advance in maturity there is a gradual increase in their resistance to citrus canker. This hypothesis is based on field observations only, but it has been found to hold true in so many cases and under such varied conditions that it is advanced here in this form to aid in other problems of citrus canker investigations and to afford a better understanding of the disease to those who are not well acquainted with it in the field. The field observations which have given rise to this hypothesis are as follows:

At Singalong, Philippine Islands, nursery trees of calamondin (*Citrus mitis*) are grown; at the time of the observation these nursery trees were two years old and were very badly affected with canker, usually 75 or 80 percent of the leaves of each tree showing infections. Mature trees of the calamondin are grown nearby, subject to entirely the same conditions of sun, wind, rain and humidity and the same sources for infection; the writer does not recall and has no record of ever having seen a canker infection upon these mature trees or upon any such mature calamondin trees throughout the Island. The calamondin is generally accepted as entirely free from canker throughout the Philippines. At Lamao, Philippine Islands, nursery trees of the calamondin are grown and are found to be very abundantly cankered; at the time of the observation these trees were a little more than one year old. In the same planting with these nursery trees occur mature calamondin trees six to seven years old; such mature trees have never shown a canker infection although other orchard trees nearby of more susceptible varieties, as well as the nursery trees, present abundant sources for infection.

Two-year-old trees of the mandarin orange (*Citrus nobilis*) are grown in nursery rows at Singalong, P. I.; as found there they were at the time of the observation very susceptible to canker, showing a large percentage of leaves with one or more infections. Nearby mature trees of the same species showed no citrus canker although exposed to the same climatic conditions and same sources of infection. Trees of the mandarin orange less than two years old were observed at Luta, in the Philippines, to be commonly affected with citrus canker; mature trees of the mandarin orange but a few feet from these young trees showed no infections from canker although exposed to entirely similar conditions of air, wind, etc., and having the same constant sources of infection.

Year-old trees of the Chu Kaa (Vermilion orange *C. nobilis*) growing at Swatow, China, were observed to be very badly cankered. The orchard plantings of mature trees of the Chu Kaa are very extensive around Swatow; although there are abundant sweet orange trees which afford sources for infection, no citrus canker infection was

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observed upon a single mature tree of this variety. Many visits have been made to the Swatow orchards at different seasons to determine this point. Many of these orchards have the susceptible year-old nursery trees interplanted among the mature trees, providing abundant sources for infection; in such cases the sun, wind, rain and humidity conditions for the young trees and the mature trees are entirely identical.

The Pong Kaa, a mandarin orange variety (*C. nobilis*) also grown at Swatow, gave the same observations. Year-old trees of this variety in many instances showed cases of defoliation resulting from canker infections; the mature trees, four or more years of age, are grown with the young trees interplanted, and show no infections whatsoever. The Pong Kaa when mature may safely be called resistant and no difficulty results from citrus canker.

Young pummelo trees (*Citrus maxima*) less than two years old are grown at Lamao and are there found to be very susceptible. As many as 90 or 95 percent of the leaves will sometimes show infections. Mature pummelo trees are grown at Lamao and throughout the Philippines. Such trees, although for the most part slightly susceptible to canker, are never very seriously affected; canker upon them causes negligible injury. Cases have been observed where such mature trees were exposed to the same climatic conditions and sources for infection as the young severely affected nursery trees, although the mature trees would remain but slightly affected.

Young nursery trees of the "Hirado Buntan," a Japanese pummelo variety, were observed at Nagasaki, Japan, to have considerable canker; at the time of the observation these trees were one year old. Under the same conditions in the same place, mature trees of the "Hirado Buntan" remained entirely free from canker; the "Hirado Buntan" is regarded as a resistant variety in Japan which may be safely grown without loss from canker.

Trees of the lemon varieties (*Citrus limonia*) less than one year old were observed at Okitsu, Japan, to be very severely affected by canker. In some cases killing of twigs resulted from girdling by canker. Mature trees four to six years old of the same varieties were grown nearby and although exposed to the same climatic conditions and sources of infection showed little or no citrus canker.

Year-old trees of the "Owari Unshiu" (*C. nobilis* var. *unshiu*) were observed in nursery rows at Okitsu and a considerable amount of canker infection was to be seen upon them. Mature orchard trees of the same variety nearby, however, showed not a single infection. The same observation on "Unshius" has been made near Kobe. These observations hold good throughout Japan, that is, "Unshiu" trees in the nurseries may frequently show an abundance of infection whereas it is very difficult to find infections on mature "Unshiu" trees.

Young trees of the "Natsu-daidai" (*Citrus aurantium* subsp. *intermedia* var. *natsudaidai* Tanaka) were observed in nursery rows at Okitsu; as grown there they showed a considerable amount of infection with citrus canker. Mature "Natsu-daidai" trees in an orchard nearby were almost entirely free from canker. The "Natsu-daidai" is grown very widely throughout Japan and very little foliage infection is to be found upon mature trees of this variety.

Seedling trees of *Poncirus* (*Citrus*) *trifoliata* were observed in nursery rows near Kobe, Japan, and were very well infected with citrus canker. Three large mature trees of the same species grew at one side of the nursery and not a single infection could be found upon them. The mature trees were exposed to the same conditions of light, wind, rain and humidity and the same sources of infection as were the nursery trees. *Poncirus trifoliata* is grown very largely for use in hedges in Japan and infection of such large mature hedges is not at all common.

Several other similar cases may be recalled but have not at the time been definitely recorded. The converse, that is mature trees susceptible while young trees under same conditions of exposure have remained free from canker, has never been observed by the writer.

Field observations such as these cannot be taken as yielding the definite conclusion that trees gain in resistance to citrus canker with maturity. The observations are, however, apparently sufficient to warrant being used to formulate a working hypothesis which may be of value in other problems of citrus canker investigations. To summarize this hypothesis and explain more clearly: Citrus trees of the more resistant species (*Citrus nobilis*, *Citrus mitis*, etc.) may often show great susceptibility to canker when young, while with increasing maturity they become but slightly susceptible or entirely free of citrus canker. Although this applies more noticeably to the resistant species it is apparently true also for the more susceptible species, such as the grapefruit (*Citrus maxima*), the lime (*Citrus aurantifolia*) and the sweet orange (*Citrus sinensis*). Such species although showing abundant infection even when mature, do not often show the twig killing and never the complete defoliation which very frequently occur on nursery trees. The wording as follows therefore, is thought to be entirely safeguarded while at the same time covering all cases; the hypothesis is advanced on the foregoing evidence that as citrus trees advance in maturity there is a gradual increase in their resistance to citrus canker.

There are of course many complex developments which might occur within the tissues to create a greater resistance to canker with maturity. There are other more simple factors which might also have the same tendency to increase resistance with the aging of the trees. The quicker response of young trees to growth stimuli may be taken as one such simple factor which contributes to some extent to the greater susceptibility of young trees. To enlarge upon this: In periods of warm, wet weather favorable for canker development, growth will also be stimulated; on young trees the effects of such stimulation is to put out new growth very quickly; on old trees the effects of the stimulus are shown more slowly and often new growth will not appear until the period of climatic conditions favorable to canker infection has passed. New growth of course in most varieties and species is essential for canker development. In other words, the climatic conditions which are a stimulus to growth of citrus trees are also in a great many cases favorable for the dissemination and development of citrus canker. The old trees exhibiting growth slowly following these stimuli, very frequently will delay the new growth enough to avoid the conditions favorable to canker development. The young trees responding immediately to

growth stimuli cause the new growth in most cases to be subjected to climatic conditions favorable to canker development. This is but one factor which may contribute to the greater resistance of older trees. Undoubtedly there may be several factors more or less complex, all contributing to cause mature trees to be less susceptible to canker than the younger trees.

The working hypothesis advanced above should be kept in mind in discussing the resistance and susceptibility of Citrus species and varieties to citrus canker. In formulating ideas as to the susceptibility of a variety, it would seem well to check all such observations upon young trees with observations upon mature trees.

Another conclusion seems noteworthy. The difficulty experienced with citrus canker upon "Unshiu" varieties in the gulf states has been rather considerable in past years. It would seem probable that with the increasing maturity of "Unshiu" orchards in those states, that greater security from citrus canker can be felt and that a condition similar to that in Japan may be arrived at; that is, that even should sources of infection arise the mature "Unshiu" orchards will have little difficulty in remaining free from citrus canker.

It would seem also from the knowledge of the differences in the behavior of young plants compared with old plants, that all statements of injury caused by citrus canker to be of the greatest value should be coupled with the information as to the age of the tree as well as with the observations on the growing conditions, weather conditions and such other data.

# FURTHER OBSERVATIONS ON A BACTERIAL ROOT AND STALK ROT OF FIELD CORN

H. R. Rosen

With Four Figures in the Text

## INTRODUCTION

In a previous publication (3) the writer called attention to a field corn disease which he attributed to bacteria. Since then additional field and laboratory studies have been made involving observations not previously reported. It seems desirable to present further studies at this time, since this disease is apt to be confused with others which show somewhat similar symptoms, and since the previous account of this disease was merely preliminary in nature. This paper will be confined to a discussion of disease symptoms, the extent of damage, varieties attacked and artificial infections.

## SYMPTOMS OF THE DISEASE

In the former publication (l. c.) it was noted that the disease manifests itself as a rotting of the roots and of the portion of the stalk to which they are attached and that individual roots showed brownish, dead areas, especially on the parts immediately joining the stem. It was likewise noted that the interior tissues of the lower nodes showed brownish discoloration and that this tissue was either dead or in a process of disintegration. Dark-brown spotting of husks, leaf blades and leaf sheaths was also noted. The disease has now been noted in other localities in Arkansas and similar symptoms, as well as others not previously described, have been observed. Most of the symptoms resulting from natural infections have been checked up by artificial infections which will be described later. The worst cases of natural infection were noted at Burdette, Arkansas. In this locality extreme cases of infection were found at the lower nodes, especially that immediately above the soil line. See figure 1. The tissues attacked showed marked decay and disintegration, appearing as a soft, dark-brown to blackish, water-soaked mass with a very strong odor of decay and involving the whole thickness of the stalk which at this point is considerably shrunken and collapsed. In the shrunken areas bacterial ooze in the form of

grayish-white slime may be observed. In such cases the stalk bends over and finally comes to rest on the ground. See figure 2. At times the attacked plant sends out secondary stalks from the portion below the attacked parts and such growths under favorable conditions may produce good-sized stalks. Often, however, the disease has apparently entirely killed the plant so that hills are represented by barren stalks lying on the ground.

FIG. 1. EXTREME ROTTING OF THE LOWER NODES OF JOHNSON COUNTY WHITE CORN. (Reduced.)

FIG. 2. STALKS FALLEN OVER AS A RESULT OF ROT AT THE LOWER NODES
Photographed at Burdette, Arkansas

Under conditions of high humidity and high temperature the decay progresses rapidly through the entire thickness of the stem, the attacked tissues collapsing and finally drying into a mass of shredded, easily disjointed fibers, remnants of the fibro-vascular bundles. Often, however, only portions of a node are found attacked, the decay varying from a dark-brown, water-soaked rot to a light-brown, dry rot, depending upon atmospheric conditions and upon age of infection. Various sized spots, stripes and blotches are also produced on stems, leaves and husks. Leaf spots are very common in the state, but most of these are of the type recently described by Durrell (1). Where nodal infections are abundant the sheaths surrounding these nodes are likewise attacked and artificial infections have been produced on sheaths, as well as various other parts of the corn plant closely resembling the natural infections here described.

All the writer's observations of this disease in the field were made on corn that had grown to good size. Attacks on seedlings and on corn at various stages of development were observed in artificial infections on material growing in a greenhouse. The localized rotting of lower nodes described for full-grown corn was also obtained on young seedlings six inches high by means of inoculations. See figure 3.

Rots produced by various fungi including Fusarium spp., *Diplodia zeae*, Verticillium and others are apt to be confused with the bacterial disease.[1] Disintegration of tissues occurs with Fusarium rots but ordinarily the lower nodes showing internal browning do not collapse and the falling over of stalks is not generally due to any localized rotted area brought about by attacks of Fusarium. Pammel, King, and Seal (2) present excellent photographs of Fusarium disease of corn and these correspond to the type of Fusarium injury found in this state. The only other disease known to the writer which may possibly be confused with this bacterial disease is Stewart's disease of sweet corn, but this, like Fusarium, is systemic, producing no localized infections comparable to those here described and is easily recognized by the yellow bacterial ooze observed in the bundles when the stalk is cut open.

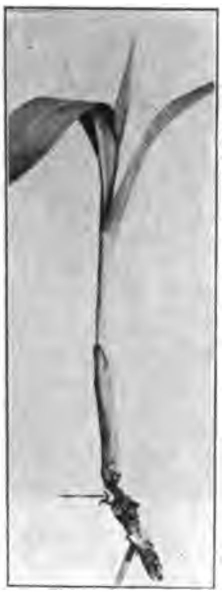

FIG. 3. Sweet cornseedling, variety "Nectar," showing lower nodal rot resulting from artificial infection.

## VARIETIES ATTACKED AND AMOUNT OF DAMAGE

The disease has now been located in several counties of Arkansas. Most of the corn grown on the farms of the Three States Lumber Company, Burdette, Arkansas, which has about 500 acres in corn, is Johnson County (white). By counts of diseased stalks per hundred, counting several hundred stalks per field, ten to thirty per cent of this corn was diseased. Quite often the disease appeared in contiguous hills of a

[1] Valleau (4) apparently questions whether there is a bacterial rot of corn. He says: "Seeds from five ears of a yellow corn grown in Arkansas were found to be badly infected with *Fusarium moniliforme*." Then he presents the following footnote: "These seeds were obtained from the farm of E. B. Whitfield, of Bauxite, Arkansas, on whose farm Rosen made his observations in regard to a bacterial root rot of corn." No comment need be made beyond stating that the "Gamble" variety of corn which was the one upon which the first studies of the bacterial disease were made is a white corn. Ninety-five per cent of the corn grown in Arkansas is white corn. Durrell (1) likewise assumes that there is no true bacterial disease of field corn and that the writer was in error in assigning certain leaf spots to pathogenic bacteria.

row, although it was also found more or less scattered. Some of the land had grown corn the year before, while some had not grown corn previously. The practice here has been to allow the stalks to stand in the field over winter and to plow them under the next spring. Besides the Johnson County corn the following fifteen varieties were found attacked. Reid's Yellow Dent, St. Charles Yellow, Boone County White, Boone County Special, Webb Watson, U. S. Selection 77, St. Charles White, Neal Paymaster, U. S. Selection 201, Biggs, Mosby, Hastings, Surecropper, Mexican June, and Huffman. Concerning the disease on these varieties, Mr. H. A. York, a graduate in agriculture from the state university, writes as follows: "The disease is found on all of them and. . . . . is worse in the lowest grounds." A white corn, known by the local name of "Gamble," and a variety of sweet corn known as "Nectar," both used in artificial inoculation experiments, were found to be susceptible. See figure 4.

## ISOLATION AND INFECTION EXPERIMENTS

Since the disease was first described by the writer the pathogen has been isolated fifteen times. These isolations were from various tissues including roots, lower nodes including both the wet rot and the dry rot, leaves and husks.

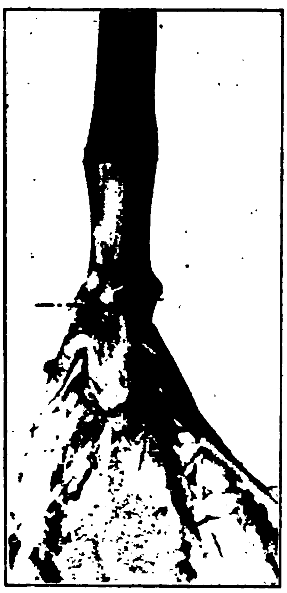

FIG. 4. ROT FROM INOCULATION AT LOWER NODE OF "GAMBLE," FIELD CORN.

The pathogen is rather easily isolated. It is a rapidly growing organism, well separated colonies appearing within twenty hours on a +1.0 peptone-beef-agar poured plate kept at 25° C. Within forty-eight hours all colonies will have appeared. In case of good-sized tissue which can easily be cut open, as at nodes, isolations are attempted by using a flamed, sterilized knife and removing bits of the internal tissue and in case of leaf tissue or of nodes in seedlings the material is first surface sterilized. Details of these isolations will appear elsewhere.

The writer in the previous publication (3) reported artificial infections on corn roots and on leaves of corn and of oats. Numerous other infections have been obtained since then, involving more than 100 growing plants. Most of these were conducted in a greenhouse, a few in the field and some in the laboratory. Two methods were used, one in which the organism was smeared on the tissues by means of a sterilized platinum loop, the tissue being previously moistened with a spray of sterilized

water, and the other in which a few cubic centimeters of sterilized water is poured into an agar slant containing a bacterial smear, the smear thoroughly distributed in the water by means of a sterilized rod and the watery suspension of bacteria sprayed on the plant by means of a sterilized atomizer. When the plants were small enough to go under a bell-jar, they were kept forty-eight hours under the jars and then taken out and put on benches in the greenhouse. All plants were grown in six- or eight-inch pots and all belljars were wrapped with paper to prevent admission of direct sunlight. When plants were too large to go under a bell-jar the moistened tissue was smeared with the bacteria and moistened cotton tied around the smear. This was the method also employed in the field with full-grown plants.

Infection can be obtained with or without wounding and apparently on any part of the growing corn. The period of incubation varies from two to four days, the average being about three days. As a rule leaf infection, through stomata or water-pores, appears within forty-eight hours after inoculation ,while nodal infections take about twenty-four hours longer to appear. It will be recalled that aerial roots as well as all lateral roots in corn are of endogenous origin, breaking through the overlying tissue before reaching the surface. This ruptured tissue invests the base of the roots in the form of collar and it appears that infection begins at these natural wounds. Artificial infections have been produced on seedlings at these collars. The old leaf sheaths which envelope the base of the stalk and which under normal conditions die and disintegrate may also serve as infection points. In the former publication (3) the writer has already reported infection by means of root hairs.

A report of the morphology of the pathogen, its cultural reactions, identity, etc., will be left for a future paper.

## SUMMARY

The bacterial disease of field corn appears as a localized rotting of roots and lower nodes of the stalk, ana as spots on sheaths, blades, and husks.

Seventeen varieties of field corn and one variety of sweet corn are known to be subject to the disease. In one locality the extent of damage in mature corn, resulting in the death of the stalks, varied from ten to thirty per cent.

Fifteen series of isolations revealed a white, rapidly growing bacterium.

Artificial infections on more than 100 plants, resulting in nodal rot, root rot and leaf spot, are reported.

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# METHODS OF DIRECT INOCULATION WITH DAMPING-OFF FUNGI

Annie E. Rathbun[1]

With Three Figures in the Text

Until the spring of 1919 Hartley (1) and his assistants had inoculated coniferous seedlings by adding the inoculum to the soil instead of by applying it directly to the seedlings. While this method of inoculation indicated great variability in the relative virulence of the different strains of fungi, there was a possibility that part of this relative virulence was due to the inability of some of the strains to maintain themselves saprophytically in the soil until the seeds had begun to germinate. Therefore, in order to eliminate this possibility, direct inoculations of both stems and roots were undertaken. The addition of the inoculum to the soil had also caused considerable germination loss but had not demonstrated whether the fungi could attack dormant seeds as well as the radicles immediately after their emergence from the seed-coats. For the purpose of ascertaining at what stage of development the fungi cause germination loss dormant seeds and radicles that had just emerged from the seed-coats were directly inoculated. During the progress of the above-mentioned experiments several new or modified methods were developed.

## DIRECT INOCULATION OF STEMS

*Inoculation at soil surface.* The seedlings for direct inoculation experiments were grown in sand in small pots in the greenhouse and were inoculated at an age when the seed-coats were still clinging to the cotyledons. In the earlier experiments the inoculum was placed on the soil surface in contact with each seedling, which was marked by a tooth-pick at the time of inoculation. A tooth-pick was also used to divide the pot into halves in case it was desirable to use two kinds of inoculum—for instance, rice and agar (figure 1). The agar inoculum consisted of approximately 4 mm. squares. These were obtained by placing a 6–8 cm. square of 4 mm. coördinate paper, the lines of which had previously been accentuated, beneath a Petri dish culture and cutting along these lines.

[1] The writer wishes to acknowledge the great assistance of Dr. Carl Hartley in the development of these methods.

*Inoculation platforms.* The practise of placing the inoculum at the soil surface was soon discontinued in favor of the inoculation platforms (figure 1). The manufacture of these was very simple. Equilateral triangles with sides ⅜ of an inch long were cut from library cards. Tooth-picks were inserted through holes made in the center of these. An ink or blue pencil mark about ⅜ of an inch below the platform indicated how far the tooth-pick was to be pushed into the soil.

FIG. 1. TOP AND LATERAL VIEW OF POT SHOWING INOCULATION PLATFORMS

An inoculation platform was placed beside each seedling and upon it in contact with the stem of the seedling was placed the inoculum. Very often one platform held the inoculum for two or three seedlings.

This new method of direct inoculation was better than the first because it prevented the fungus from growing from one seedling to the other through the soil, and if the seedlings were examined daily, the exact point where damping-off began could be readily ascertained. This method has been used with apparent success in a rather large series of inoculation experiments.

CELLULOID CONES AS DAMP CHAMBERS

Modifications of Hubert's (2) celluloid cylinders were employed to provide damp chambers for these experiments. They consisted of truncated cones 5 inches high and 2½ inches in diameter at the base.

They were manufactured by the same method and from the same grade of celluloid—the thinner of the two grades of transparent celluloid such as is used for windows in automobile tops—that Hubert employed. "The edges" were "fastened together by means of acetic ether (ethyl acetate) applied by dipping a camel's hair brush in the liquid and running it quickly along the edges to be cemented." The two edges were kept firmly pressed together until dry (figure 2).

For use with pots, cones were much better than cylinders, because it was comparatively easy to get a tightly fitting cone without manufacturing one for each individual pot, and they could be nested and stored or transported in much less space.

FIG. 2. CONE DAMP-CHAMBER

The top of each cone was plugged with cotton wet in boiled water—moisture being furnished in this manner instead of by placing a piece of cotton inside as Hubert did. In case the sand itself became dry the pots were set in boiled water in sterilized pans. This indirect method of watering was necessary because overhead watering would have necessitated the removal of the cones, washed away the inocula, and moved the platforms.

As soon as the experiment no longer required damp chamber conditions the cotton was removed from the top of the cones. The cones still minimized, although to a less extent than before the removal of the cotton, the danger of contamination from such fungi as Fusarium and Botrytis which spread through the air. The use of boiled water prevented infection from water-borne fungi. As an additional precaution against accidental contamination each damp chamber was sterilized at the beginning of each experiment with a strong solution of formalin or mercuric chloride.

### DIRECT INOCULATION OF TAP ROOTS

At the same time that some of the direct stem inoculations were being carried on, the tap roots of young seedlings were also directly inoculated. Three methods of inoculation have been tried with apparent success in a rather limited number of experiments.

The first and best method was to cut away one-half to two-thirds of a Petri dish culture; then to place the seedlings in the Petri dish in such a way that the roots were in contact with the inoculum while the stems merely touched the glass (figure 3).

A second method was to grow the fungi on rice mush in Erlenmeyer flasks. Several grains of the rice and the fungus growing upon them were transferred to the bottom of a sterile Petri dish. Then the seedlings to be inoculated were laid in the Petri dish with the root of each seedling in contact with the inoculum at one point while the remainder of the root and the stem rested against the sterile glass. With this latter method the seedlings showed a slight tendency to wilt.

In order to overcome this tendency the bottom of each Petri dish was lined with moistened filter paper before the inoculum was transferred to it. Otherwise this method did not differ from the second.

FIG. 3. INOCULATION OF TAP-ROOTS

Checks for each of these methods consisted of seedlings inoculated with sterile rice or agar. The fact that the check seedlings usually remained healthy seemed to prove that the root-rots were really caused by the introduced fungi and not by physiological changes brought about by the removal of the seedlings from the sand in which they had been grown.

DIRECT INOCULATION OF DORMANT SEEDS AND RADICLES JUST EMERGED FROM THE SEED-COATS

In order to ascertain whether or not damping-off fungi attack dormant seeds, it was necessary to germinate the seeds under conditions that made it possible for the observer to distinguish the ungerminated seeds from seedlings which were killed immediately after the emergence of the radicles from the seed-coats. Inoculation of the soil proved entirely useless for this purpose and a few small preliminary trials demonstrated that sowing seeds broadcast over a poured plate was not a good method because germination was poor even in the controls. Therefore, two hollow rectangles about 5/8 of an inch wide and 2 inches long were cut in the interior of each Petri dish culture. Coördinate paper in which rectangles of the desired size had been drawn served as the pattern. The seeds were arranged along the perimeters of these rectangles with one side of each seed in contact with the inoculum. This method was better than sowing the seeds broadcast because (1) it did not smother the seeds; (2) it inoculated the seeds less heavily; (3) it made it easier to count the number of germinating seeds.

By this method radicles which had just emerged from the seed-coats were inoculated. If the seedlings were not attacked at this stage they generally continued to grow in the Petri dish, developing stems and cotyledons. The radicles which had just emerged from seeds previously germinated on filter paper were also inoculated by placing them in contact with rectangles of agar inoculum in sterile Petri dishes.

## SUMMARY

The results of the methods described above will be published in detail elsewhere. (1) The direct inoculation of stems indicates that there is considerable variability in the relative virulence of the different strains and that a few of them were formerly considered non-parasitic apparently because of their inability to live in the soil. (2) The inoculations of tap-roots indicate that, although the methods should be tried out more extensively before definite conclusions are drawn, good results can be secured by their continued use. (3) The experiments with dormant seeds apparently confirm the assumption that by far the greater part of the germination loss is caused by the attack of radicles which have just emerged from the seed-coats rather than by attack of dormant seeds.

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## BRIEFER ARTICLES

### SOFT ROT OF PEPPER FRUITS

S. G. Lehman

During the rainy weather of July of the present year, a new disease of cultivated sweet peppers (*Capsicum annuum* var. *grossum*) appeared in the writer's garden at West Raleigh. As examination of available references indicates that this disease has not been described in pathological literature, it seems desirable to make a record of the trouble at this time.

The variety of pepper on which the disease appeared is a hybrid between the commonly cultivated forms of *C. annuum grossum* known as the Chinese Giant, and the pimento, the plants having been produced by Mr. L. R. Detjen, now associate horticulturist of the Delaware Agricultural Experiment Station. The disease has been found only on fruits, and natural infection has always occurred at the blossom end of peppers not more than six or eight inches above the ground. The trouble does not promise to become of much consequence economically as comparatively few fruits have been attacked.

The disease appears first as a small water-soaked spot at the point of inoculation. The infected area enlarges rapidly, becoming soft, watery, slightly sunken and somewhat lighter in color in contrast with the surrounding deep green uninvaded tissue. The parasite soon pervades the particular locule in which infection has occurred, and, within a period of four or five days, permeates the entire fruit, causing a soft, wet rot, with a brown surface discoloration. The epidermis remains unbroken and the discolored and misshapen fruit clings to the plant for several days. When infected fruits are kept in moist chambers, the fungus comes to the surface only where the epidermis has been broken, and at these places an abundant growth of white cottony mycelium is produced quite free from fruiting structures of any kind.

If a small portion of the infected area of the pericarp is crushed under a cover glass, the cells easily separate, and it can be seen that the tissue is permeated by an abundant mycelium of a phycomycetous nature. Pure cultures of the invading organism are easily obtained by sterilizing the unbroken surface of an infected fruit with mercuric chlorid solution and planting small pieces of invaded tissue in Petri dishes containing Czapek's nutrient solution solidified with agar-agar. An abun-

dant growth of sterile, non-septate mycelium is produced within a few days. When bits of infected tissue are put into water, in a watch glass kept at room temperature, branches of the mycelium grow into the water for a distance of a few millimeters and begin the formation of oogonia and antheridia within six or eight hours. This fruiting period continues for four or five days. At the end of this time, great numbers of oospores are present in and around the host tissue.

The mycelium branches irregularly, is non-septate, and finely granular when young, the hyphae having a diameter of 4–4.5 microns when two or three hours old. Old hyphae are coarsely granular, irregularly septate, and from 4–8 microns in diameter. Oogonia are globular, thin-walled, hyaline, and have a diameter of 16.5–23.7 microns (commonly 20.5–22.5 microns). Oospores are spherical, and they have a smooth light-brown wall which is often 1.5 microns thick. Their diameter is 12.4 to 18.4 microns. A rest period of considerable length is required before germination.

Antheridia are of two kinds, namely: stalk antheridia and branch antheridia. The stalk antheridium is a single cell which adjoins the oogonium and is formed by the production of a septum near the distal end of the oogoniophore. The branch antheridium consists of an enlarged cell at the end of a hypha which commonly, but not invariably, arises as a branch of the oogoniophore. Branch antheridia are club-shaped, possess a diameter of 6–6.5 microns and adhere closely to the oogonial wall. Fertilization tubes were readily seen in connection with both types of antheridia. Notwithstanding attempts to produce them by growing the fungus on animal tissue as suggested by Butler (2), no zoosporangia have been observed.

On animal tissue such as ants and flies, a profuse vegetative growth is produced, but no fruiting occurs except when the host tissue is immersed in water. Very few septa are to be found apart from oogonia and antheridia. A single hypha may possess diameters varying from 4–8 microns, measurements of adjacent portions frequently differing by 1–1½ microns. Oogonia and oospores are somewhat larger than corresponding structures produced on vegetable host tissue.

Attempts to accomplish artificial inoculation of healthy fruits were made in a number of ways. Pieces of pepper tissue bearing mycelium and oospores were placed on pepper fruits still attached to the plant and the whole was covered with a moist chamber for 48 hours. No infection occurred. A watch glass containing pieces of infected tissue forming oospores in water was so placed that the blossom ends of fruits hung suspended in the water for two days. Even when the fruit had been pricked with a needle, no infection resulted from this treatment.

Failure of infection by this method was possibly due to the fact that no zoosporangia had been formed and no zoospores were present to find their way into the wound. When bits of mycelium are forced through the epidermis into the tissues of the pericarp, a rapid growth of the fungus and consequent decay of the fruit ensues. Successful inoculations were made also by the latter method on the variety *C. annuum longum.*

The fungus causing the rot of pepper fruits described above is believed to be *Pythium de Baryanum* Hesse. A comparison of the pepper organism with *P. de Baryanum* as described by Atkinson (1) reveals sufficient similarity to substantiate the conclusion that they are one and the same species.

The result of the attempts to produce artificial inoculation taken together with the circumstance that natural infection has been found on fruits not more than six or eight inches away from the ground indicates that infection is accomplished naturally by zoospores splashed from the ground by rain and that they enter through wounds produced by insects. Search was made of the plants for insects which might be responsible for wounds on the fruit, but none were found.

AGRICULTURAL EXPERIMENT STATION
WEST RALEIGH, N. C.

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## RUST OF ONION FOLLOWED BY A SECONDARY PARASITE

J. C. WALKER

WITH TWO FIGURES IN THE TEXT

The occurrence of an aecial stage of rust was noted on leaves and seed stems of top onion (*Allium cepa* var. *bulbellifera*) at Madison, Wisconsin, on June 17, 1920. The lesions were scattered, light yellowish in color, roughly circular to oblong in shape with distinct margins, and varying from one to twelve millimeters in diameter. See figure 1A. The surface of the diseased area was slightly raised. The aecia appeared as golden yellow, raised spots which eventually rifted the epidermis. The margins of the mature sori were incised and slightly

reflexed. The aeciospores were orange to yellowish, angular, smooth-walled, with granular contents, giving them the appearance of being verruculose; 17–22 ×19–24µ. Specimens submitted to Dr. J. C. Arthur were diagnosed as probably a case of *Puccinia asparagi*, crossing to onion, which supposition was supported by the fact that the two infected onion plots were separated by a patch of asparagus. No aecial form was noted on the latter at the time, which was to be expected from

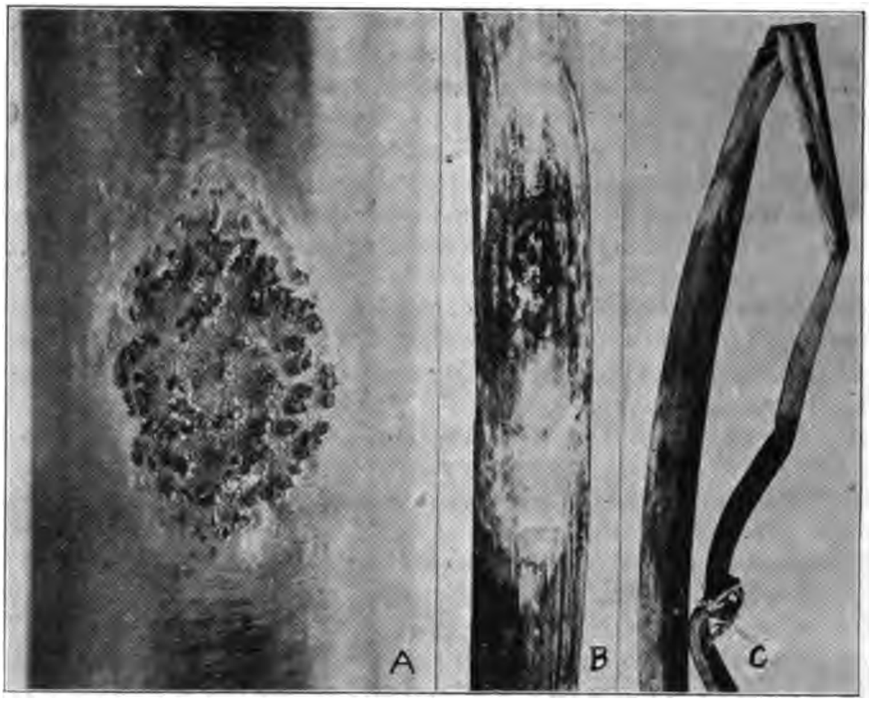


FIG. 1. *A*. Onion seed stem bearing lesion of aecia of the asparagus rust, *Puccinia asparagi* × 6. *B*. Botrytis sporophores appearing on the aecia × ¾. *C*. Onion stem finally girdled by the Botrytis × ½.

the fact that the crop had been cut closely up to that date. Late in the season, however, (September 16) many of the asparagus seed plants bore an abundance of uredinia and telia of *Puccinia asparagi*. The above description of the aecial stage on onion agrees closely with that of the asparagus rust. Sheldon (2) has successfully crossed the asparagus rust to onion, producing all three stages on the latter.

Collections of aecia on winter or top onions have been previously made by Holway (1) and by Sheldon (2) during the latter part of May

and in June. In each instance asparagus was growing nearby. The only other aecial form reported on onion and answering to this description is that of *Puccinia porri* Wint. According to Tranzschel (3), however, *P. porri* is a Hemi-puccinia; he sowed the sporidia on Allium and obtained uredospores direct.

On June 27 a re-examination of the infected onion plants showed invasion by a secondary organism by way of the rust sori. Light grey, sunken, linear lesions, irregular in outline but with definite margins, surrounded many of the rust pustules. Oftentimes these appeared before the sori were open and in consequence the aecia failed to mature. In every case, the remains of a rust pustule was found in the center of such lesions. See figure 2 and 1 B. The new lesions continued to enlarge quite rapidly and following a period of rainy weather sporulation characteristic of Botrytis appeared invariably on the dead tissue. Eventually, nearly every rust lesion found in the field showed evidence of invasion by Botrytis, and no infection by this fungus other than by way of rust sori was noted. The seed stems were eventually girdled, resulting in the upper portions falling over. See figure 1C. The actual loss in this case was not serious since the top sets were nearly mature before many stems were girdled. Should such an attack occur upon seed plants of the common onion, however, considerable damage might result. A pure culture of the Botrytis form was obtained and wound inoculations into white onion bulbs were made. No signs of decay resulted, indicating the species to be different from those causing onion neck rot. Apparently it is capable of invading only as a secondary organism. Specimens and cultures have been preserved for identification and further study.

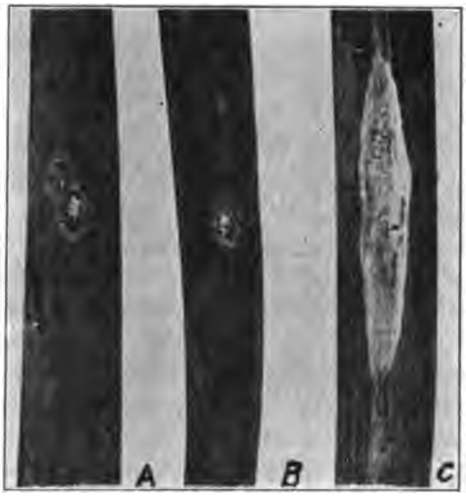


FIG. 2. *A*, *B*. Rust lesions on onion seed stems invaded by *Botrytis* sp. Note the small, light-colored, sunken spots in the rust pustules × ¾. *C*. The linear lesion developing around an immature rust pustule × ¾.

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## NOTES ON THE CITRUS-ROOT NEMATODE, TYLENCHULUS SEMI-PENETRANS COBB

L. P. BYARS

WITH ONE FIGURE IN THE TEXT

During the years 1914 to 1917, inclusive, the writer, while prosecuting active investigations on various nematodes attacking plants, had opportunity to make certain minor observations and studies on the nematode *Tylenchulus semipenetrans* Cobb, which parasitizes the roots of citrus species. These consisted mainly of observations on its distribution in the state of Florida, of studies of the symptoms of the disease both on the top and roots of citrus trees of various kinds, and of certain preliminary experimental work on control. The results were sufficient to indicate that the organism may prove to be a serious factor in connection with the citrus industry. It seems desirable to record the results of these incidental studies at this time, since the writer is contemplating a change of duties which will not permit of further work upon this parasite. Further experimentation appears to be important.

Thomas (5) in 1913 made the initial report of the occurrence of this nematode in California. The parasite has since been discovered on citrus from many parts of the world. Cobb (2) in 1914 found it on citrus material collected from one point in Florida and from California, Spain, Malta, Palestine, and Australia. In 1915 Trabut (6) reported the nematode on collections from Algeria, and advocated control methods involving the use of chemicals. In so far as is known by the writer, it has not been reported to occur in other countries.

## DISTRIBUTION

At one time or another the writer has examined trees in all of the main citrus growing sections of Florida for nematode infection, and has found it at only three points, namely: Glen St. Mary, Gainesville, and Brooksville. The infection at Glen St. Mary was observed on 10- to 15-year-old grapefruit trees growing in a variety test on a well drained, dark, loamy soil. At Gainesville it was found to a slight extent on a few 6- to 8-year-old orange trees growing on very light sandy soil in the test grove of the Florida Agricultural Experiment Station. Severe infection was discovered on nearly all of a large variety of citrus plantings being tested at Brooksville, Florida, at the Plant Introduction Field Station of the U. S. Department of Agriculture. The trees were growing on a poorly drained loam soil—so-called hammock land—and as a rule were not in a healthy vigorous condition. Thus it seems that the nematode does not occur generally over the citrus sections of Florida, as is the case in California according to the report of Thomas (5). Its occurrence at these three points in Florida is significant in view of the fact that at each of these places there has been considerable introduction of citrus stock from other states and even from foreign countries.

In 1917 the writer was enabled, through the courtesy of members of the Office of Seed and Plant Introduction of the U. S. Department of Agriculture, to make what seems to be a significant discovery of the nematode. It was found on the roots of citrus seedlings which had been collected in Brazil by Dorsett and others (3). Some of these seedlings were tangerines, *Citrus nobilis deliciosa* (Tenore) Swingle, but the majority were navel oranges, *Citrus sinensis* (L.) Osbeck, or the species of citrus, "white selecta," from which our Washington navel oranges originated. It therefore seems quite possible that the nematode may have been originally introduced into the United States from Brazil along with early importations of citrus stock.

## APPEARANCE OF AFFECTED TREES

Thomas concluded after making examinations of a large number of trees in California that, with few exceptions, a mottling of the leaves accompanied nematode infection and that the nematode very probably was an important factor in causing malnutrition, mottling, or deterioration of many citrus groves. The writer's observations differ somewhat from these in that he has been unable to find on the aerial parts of infected trees definite signs of disease which could be used as reliable criteria for the presence of the nematode on the roots. An abundance

of the parasites have been noted on both young and old trees which showed severe frenching, leaf mottling, dieback, general loss of vigor and growth, or other troubles of this nature; and likewise the organism has been found in great numbers on trees which presented none of these abnormal appearances and which were apparently vigorous and healthy. Furthermore, nematode-free trees growing in badly infected groves were discovered that exhibited to a marked degree one or more of the pathological symptoms just mentioned. These conflicting results were secured from the microscopic examination of a large number of representative trees on the Plant Introduction Field Station of the U. S. Department of Agriculture at Brooksville, Fla., and in other groves. That the organism is an active injurious parasite there can be little doubt, but the writer thinks there is still lacking observational and experimental evidence to show clearly its symptomatic effect on the aerial portion of trees.

FIG. 1. PHOTOMICROGRAPH SHOWING A GROUP OF ADULT AND DEVELOPING NEMATODES ON THE FIBROUS ROOT OF A CITRUS SEEDLING IMPORTED FROM BRAZIL. × 60

On the root system of affected trees it is likewise difficult or impossible to detect sure signs of infection unless the nematodes themselves are seen. An abundance of the parasites were found on roots which appeared to be sound and normal. Moreover, few of the nematodes could be found on old dead roots. This indicates that perhaps as with other parasitic nematodes the organism leaves the host tissues as soon as the latter die. Infection can be determined with certainty only by detection of the causal nematode *Tylenchulus semipenetrans*, larval and adult stages of which may be readily seen with the aid of a hand lens adhering to the fibrous roots. In figure 1 is shown a characteristic group of adult or developing nematodes attached to the root by means of their anterior ends which are embedded in the tissues. While such adults can be seen even with the unaided eye, the writer has found that, by placing suspected roots in a Syracuse dish of water and examining with a dissecting binocular microscope a rapid and much more satisfactory examination of the roots can be made.

The citrus nematode in the adult stages is not likely to be mistaken for other nematodes. So far as the writer's observations go, no other nematode parasitizes citrus. However Neal (4), who in 1889 worked in Florida on the common root knot nematode, *Heterodera radicicola* (Greef) Müller, claimed that this organism produced galls on the roots of citrus. The writer has repeatedly tried without success to infect in greenhouse and field various species of citrus with the root-knot nematode, and has also made a large number of examinations of citrus roots growing in the field beside roots of other plants which were severely infected, without ever finding them parasitized. Bessey (1) and other investigators report similar observations.

## HOT WATER TREATMENT

Favorable results secured by the writer from the use of hot water in killing the root-knot nematode when embedded in the tissues of certain tuberous crops suggested the possible application of this means to the eradication of the citrus nematode from the roots of seedlings or young trees. Consequently, on June 25, 1915, at Brooksville, Fla., the writer treated, in lots of three, the roots of badly infected young citrus trees by placing them in water at different temperatures for various lengths of time, as follows: 110° F. for 20 min.; 120° F. for 15 min.; 125° F. for 15 min.; 130° F. for 10- and 15-minute periods; 135° F. for 10 min.; 140° F. for 10 min. In addition three severely infested trees were placed in tap water at room temperature for 25 min. and used as a check. All seedlings were set out immediately after treatment in the open in isolated plots on non-infested land. A final examination of the roots of the trees was made on August 10, 1916. An abundance of the citrus nematodes was found on the check trees and on those treated at 120° F. for 15 min. but none could be detected on those treated at any of the higher temperatures. Those trees treated at 135° and 140° F. respectively were dead and the others for the most part showed ill effects from the treatments. This, however, is not surprising, as the hot water submersion was given in midsummer at a time when the trees were actively growing. In winter they could very probably withstand much higher temperatures and longer exposures without injurious effects. The results of this single limited experiment indicate that there may be practical possibilities in hot water treatment for the elimination of this pest from nursery stock.

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## THE TRANSFERENCE OF POTATO LATE BLIGHT BY INSECTS

W. J. MORSE

Records of undisputed transference of the spores of parasitic fungi by insects are by no means lacking in phytopathological literature. As a rule, however, these represent cases where the spores are more or less resistant to drying. The conidia of the potato late blight fungus, *Phytophthora infestans* de Bary, being thin-walled and very delicate, hardly belong to this class. Undoubtedly most pathologists with considerable field experience with late blight would agree that under favorable weather conditions it is probable that certain insects play an important role in transferring the disease between adjoining plants and in distributing the conidia from one portion of an affected plant to another. The writer, at least, has always thought it improbable that late blight is carried any distance in this way from field to field. The following observations suggest that under especially favorable conditions such may be the case.

A small greenhouse is maintained in connection with our plant disease work. During a considerable portion of the year it is used largely for growing potatoes for experimental purposes. No greenhouse studies have ever been made on late blight there and no potatoes affected with late blight rot have ever been planted in this house. With one exception the plants have always been free from this disease.

Early in September, 1915, the house was practically filled with rapidly growing potato plants. One of these, located near an open win-

dow on the south side, developed a severe case of late blight, and the disease spread rapidly through the house. It was noted that the flea beetle, *Epitrix cucumeris* Harris, and the pink and green potato aphid, *Macrosiphum solanifolii* Ashmead, were by no means uncommon on all of the plants.

Weather conditions had been very favorable during the previous eight weeks for the development of blight in the fields. There were 13 rainy days each in July and August, or 26 out of 62. During this period the total rainfall at Orono was 11.34 inches. The only growing potatoes within half a mile or more was a small plot of several varieties located about 150 yards northeast of the greenhouse. An examination showed that these plants were in the last stages of destruction by late blight, but the causal fungus was still fruiting abundantly on those leaflets which were partially alive.

The greenhouse had no open ventilators or windows facing toward this plot of blighting potatoes, moreover taller buildings, lying between, still farther prevented the possibility of the spores of the blight fungus being carried by wind from the field to the greenhouse. Flea beetles were present in great numbers on the potato plants in the field. The aphids were less plentiful, but were numerous. These facts suggested that the blighting field mentioned was the source of the infection in the greenhouse and that the insects in question acted as carrying agents.

Conditions prevented making an actual demonstration that the disease could be communicated from diseased to healthy plants by transferring the insects from one to the other, for no plants were available which had no possibility of not being already infected. An attempt was made to determine if the conidia of the fungus could be demonstrated by microscopic examination as adhering to the bodies of the insects. A large number of both species were examined in this way, both from the greenhouse and from the field. No spores were found on any of the insects that came from the greenhouse and none on the plant lice from the field, but an occasional one could be found adhering to the bodies of the flea beetles. Twenty or more flea beetles, collected from plants in the field, were placed in each of a number of small vials. The vials were partly filled with distilled water and the mixture of insects and water vigorously shaken. Then the liquid was, either with or without the insects, transferred to a small centrifuge tube and centrifuged for several minutes. An examination of the sediment at the bottom of the tube in a number of, but by no means all, cases, showed one or two conidia of the late blight fungus.

While circumstantial evidence strongly indicated that either the flea beetles or the potato aphids were the responsible agents in carrying the disease from the field to the greenhouse, positive proof of this was not obtained. No positive evidence was obtained that the spores of the fungus adhered to the bodies of the aphids. On the other hand it is apparent that the flea beetle may act as a carrier, but this is by no means the universal rule where they are taken from plants on which an abundance of the conidia of the late blight fungus are being produced.

MAINE AGRICULTURAL EXPERIMENT STATION

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## LIGHTNING INJURY TO POTATO AND CABBAGE[1]

C. R. ORTON

WITH ONE FIGURE IN THE TEXT

### POTATO

The writer had an opportunity at Girard, Pa., in 1919, to observe carefully a field of Petoskey potatoes which had been struck by lightning. The injured patch was first observed by Mr. Mohring, the owner, on August 22, after a severe electrical storm two days previously, but it was not until August 29 that the following observations were made:

The area which involved about 125 plants was nearly circular in outline, being about thirty feet in its greatest diameter. When observed by me, all the plants in the center of the area were killed—those nearer the margin were nearly dead and the injury became less as the plants were further removed from the center. The stems of the more severely affected plants were collapsed from near the ground upwards for several inches and often nearly to the tip. At this time the cortex was whitened where it had not already become overgrown with saprophytic fungi. The pith at and just above the ground was hollow and white. The greener portions of the stems showed a flattened or compressed condition with the pith browned and the xylem region sometimes brown. The pith from the ground to the attachment with seed piece was not hollowed but was usually browned to within a short distance from the old seed piece. The pith in some of the lateral branches was also browned for a short distance from the nodes.

[1] Contribution from the Department of Botany, The Pennsylvania State College, No. 28.

The severest injury appeared two or three inches above the ground where the stalk was entirely dead and sometimes, though not always, split. Occasionally a stalk in an affected hill seemed to escape the injury. It was noticeable that when such a condition was found the largest stalk was the one which always showed the most pronounced injury.

It should be noted that these observations were made nine days after the injury took place and the symptoms exhibited were undoubtedly in the later stages.

## CABBAGE

No reference has been found to lightning injury on cabbage, although Professor L. R. Jones reports in Phytopathology 7: 140–141, 1917, a case of lightning injury to kale occurring in Michigan.

On July 29, 1920, while passing through Erie, Pa., I visited the office of S. S. Lehman, County Agent, and was shown some cabbage plants which had been brought to him the day before from near Edinboro, Pa. The grower reported that a circular spot had appeared suddenly in the field and seemed to be spreading. An examination of the plants immediately suggested to me the probability of lightning injury and arrangements were made to visit the field. This was done on August 1.

FIG. 1. CABBAGE FIELD SHOWING AREA KILLED BY LIGHTNING
Photographed by courtesy of S. S. Lehman

The cabbage field consisted of about fifteen acres in which the stand was very uniform except in two or three low spots where the plants had been drowned by the frequent rains.

The spot in question was upon the higher, better drained portion of the field, was almost circular in outline and about thirty-five feet

across, involving eleven rows. At this time all the plants in the center of the area were dead and shriveled up. The plants near the margin showed progressive stages of the injury and a rather careful examination was made. See figure 1.

The most noticeable injury occurred about two to three inches above the ground where the stems were shriveled on the more seveerly injured plants. On the plants showing lesser injury, dark purplish spots were produced upon the stem involving those portions just above and about the lower leaf bases. In some cases these purplish spots had faded and become light brown. In almost every case the mid-veins of the lower six or eight leaves showed marked injury on both sides, taking the form of collapsed, shriveled tissue.

No evidence was seen of any vascular discoloration. Aside from the noticeable injury upon the stems and mid-veins the most characteristic symptom appeared to be the destruction of the pith from a point just below the origin of the "head-leaves" nearly or quite to the ground. There was little discoloration of the region around the pith but there seems no doubt about the injury bringing about this very pronounced effect. The delicate structure of the pith possibly accounts for its striking destruction.

It seems probable that the very characteristic necrotic areas involving the cortex about the leaf-bases may have been caused by an accumulation of water at these points. More careful observations are needed on the conditions present at the time of lightning injury but it seems probable that the injury is greatest at the points where water has accumulated. This would account for the severe injury on the mid-veins and stems just above the ground—and would also perhaps account for the frequent absence of injury to the portions below ground. More observations are needed on the effect upon the pith of plants injured by lightning, but in the several cases observed by me upon potatoes and the one case upon cabbage it was most pronounced and may prove to be a help in diagnosis.

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## PHYTOPATHOLOGICAL NOTES

*The mucilage of mistletoe berries as an adhesive.*—It is not generally known that a very effective adhesive may be made from the mucilaginous or viscid endocarp of the berries of Phoradendron, Viscum, and related genera. A thin paste may be prepared by beating up the berries in water. The residue from the crushed fruit may then be strained off and the solution allowed to evaporate to the desired consistency. A low alcohol, phenol or some other preservative that will not cause coagulation, may be added. This preparation will keep indefinitely, and has been used by the writer in herbarium work, and in many cases was found to be more effective than the ordinary library paste of the trade. It is possible that the preparation may be found of use in microscope and microtome technique. An adhesive may also be extracted from the berries of Razoumofskya species.

Many species of Phoradendron in the south and southwest produce berries in large quantities. In some sections Razoumofskya species are sufficiently abundant to admit of the collecting of berries in considerable quantities.

The adhesive nature of the mucilaginous content of these berries, especially in the case of the Phoradendrons, is probably of considerable commercial importance, and is worthy of further investigation.—James R. Weir.

*Polyporus dryadeus (Pers.) Fr. on conifers in the Northwest.*—*Polyporus dryadeus*, the cause of a well-known heart rot in various dicotyledonous trees, especially oaks and poplars, occurs rather frequently on conifers in the Northwest. The fungus delignifies the heartwood of the base and roots of living trees and may be the cause of windfall. The fungus most frequently occurs on *Tsuga heterophylla* and *T. mertensiana*, but it has also been collected on *Abies grandis* and *Picea engelmanni*. Collections have been made on conifers from Washington, Oregon, Idaho and Montana. The fungus is also found on various species of oaks and maples in the West. This note verifies the report made by W. H. Long (Jour. Agric. Research 1: 247, 1913) on specimens of *Polyporus dryadeus* collected by C. J. Humphrey on *Tsuga heterophylla* in Washington.—James R. Weir.

*Septoria Negundinis Ellis & Ev. in Zion National Park.*—On July 22 of the present year the writer visited Zion National Park, Washington County, Utah. Upon arriving at the Wiley camp, one is impressed with the immense box-elder trees which form a sort of a lane in front of the park. At the time of the visit, however, apparently every loaf of every tree was affected by what subsequently was determined as *Septoria negundinis* Ellis & Ev. The trouble was locally attributed to the effect of a late frost which had been unusually destructive. Some of the spores of the Septoria are more than three-celled.—A. O. GARRETT.

*The Imperial (British) Bureau of Mycology* (to which a reference was made in Phytopathology, 9, p. 265, June, 1919) has now been established at Kew, where it will work in close coöperation with the Director and Staff of the Royal Botanic Gardens. Dr. E. J. Butler, until recently Joint Director of the Agricultural Research Institute, Pusa, and Imperial Mycologist (India), has been appointed Director, and has commenced work at the headquarters of the new bureau, No. 17, Kew Green, Kew, Surrey, England. It is intended to set up a central agency for the accumulation and dissemination of information on all matters concerning the diseases of plants caused by fungi, and for the identification of specimens, on behalf of workers in the overseas parts of the British Empire. There are over fifty appointments of professional mycologists or plant pathologists now sanctioned in the overseas Dominions, Colonies and Protectorates, and in many cases the work is carried on under conditions of considerable isolation. It will be the aim of the Bureau of Mycology to serve as a link between these workers and those in other parts of the world, and to become a central clearing house for the good of all. Specimens received for identification will be dealt with in part by the Bureau (where culture work on pathogenic fungi will be carried on) and in part by distribution to specialists in particular groups. Information will be circulated, if funds permit, by means of an abstracting journal on the lines of the "Review of Applied Entomology," and also by direct correspondence. Separates of original papers will be lent to isolated workers, and the Bureau is issuing an appeal to be supplied with two copies of separates from all who can spare them, to provide for this part of its activities. The need for some central organization on these lines has long been felt by workers in many British Colonies, and the Bureau, which is supported entirely by contributions from the Colonies, has been established to meet a definite demand.—E. J. BUTLER.

*The Phytopathological Society of France.*—Believing that the Plant Pathologists of America may be interested in a few facts regarding the

Phytopathological Society of France, I am offering the following brief statement based upon information given to me by M. Etienne Foëx upon the occasion of his visit here this past summer. The Société de Pathologie Végétale de France was founded in May, 1914. The first president was Professor Mangin; the first secretary general was M. Hariot; the second secretary general was M. Arnaud. The president for 1921 is Professor Viala; the secretary general for the same year is Etienne Foëx. The association issues a publication monthly in four fascicles under the title, Bulletin de la Société de Pathologie Végétale France. The society meets once a month at 63 rue Buffon, Paris Ve. The Association includes both plant pathologists and entomologists, and papers on both plant pathology and entomology appear in the Journal. The price of this Journal including membership in the Association is 12 francs. Non-members pay 14 francs per year. Anyone interested in the society or the Journal should address inquiries to M. Foëx at the Station de Pathologie Végétale, 11 bis rue d' Alesia, Paris (14e).—H. H. WHETZEL.

*List of literature on phytopathology.*—In view of the fact that this list is to be omitted from the current numbers of Phytopathology, the mimeographed list of current botanical and pathological literature issued every two weeks from the Library of the Bureau of Plant Industry will be sent to members of the Phytopathological Society requesting it. This list is a coöperative undertaking of the Library and the Office of Economic and Systematic Botany of the Bureau of Plant Industry. Miss A. C. Atwood, bibliographical assistant of the latter office, examines the periodicals and does the indexing, while the list is prepared and issued from the Library. Where there are several persons at the same experiment station or institution, we would prefer to send the list to the library or some central office to be distributed from there to individuals. This would materially reduce the amount of addressing and mailing to be done from Washington. Will all persons who wish to apply for the list, or who wish information concerning it, write to Miss Eunice R. Oberly, Librarian, Bureau of Plant Industry, Washington, D. C.—E. R. OBERLY.

*Biography and portrait of Dr. F. Kolpin Ravn made available.*—Arrangements have been made by the departments of plant pathology, Cornell University and the University of Wisconsin, with the Office of Cereal Investigations coöperating, to furnish practically free, biography and photograph of the late Dr. F. Kolpin Ravn, of Denmark. The biography is an English translation by Mrs. Ravn

from the original by Carl Ferdinandsen published in Danish. Requests for the biography and photograph should be made to Dr. A. G. Johnson, College of Agriculture, Madison, Wisconsin, with ten cents in stamps enclosed to cover postage and wrapper.

*Personals.*—Mr. E. J. Wortley has resigned his position as Director of Agriculture in Bermuda to accept a similar position in Nyasaland. Mr. Wortley has made extensive studies of leaf-roll and related diseases of the potato. He is succeeded in Bermuda by Mr. E. A. McCallan, a native Bermudian and graduate of the Ontario Agricultural College, who has been First Assistant in the Agricultural Station in Bermuda since 1913.

Mr. Paul V. Siggers, Scientific Assistant, Office of Investigations in Forest Pathology, has resigned to accept the position of Pathologist with the United Fruit Company. He will be stationed at Changuinola, Panama, mail address, Box 3, Bocas del Toro, Panama. He will investigate diseases of the cocoanut palm and cacao.

Mr. Rush P. Marshall, Pathological Inspector, Office of Investigations in Forest Pathology, has accepted a similar position with the Federal Horticultural Board. He will be engaged in the work on potato wart.

# ABSTRACTS OF PAPERS PRESENTED AT THE FOURTH ANNUAL MEETING OF THE PACIFIC DIVISION, AMERICAN PHYTOPATHOLOGICAL SOCIETY, SEATTLE, JUNE 17–18, 1920.

*Preliminary experiments on injury to wheat from seed treatment in Washington.* GEORGE L. ZUNDEL

Samples of wheat from a large number of localities in the Pacific Northwest, especially from Washington, were treated with a standard bluestone solution (1 lb. to 5 gal. water) for ten minutes. The resulting seed injury varied from 12 to over 60 per cent. Hand-threshed wheat was injured scarcely at all. When treated with formaldehyde solution, 1–40, the injury ranged from 8 to 80 per cent. The injured seed varied with the seed lot of a given variety and with the manner in which the seed was threshed. When the high speed cylinder machines are used very dry grain sustains numerous small cracks that allow the fungicide to enter to the germ and cause injury. Wheat dipped in a lime solution for 3–5 minutes after treating with either bluestone or formaldehyde sustains little injury. In each of 5 field tests beneficial results were obtained by the use of the lime bath. The use of lime after formaldehyde gave slightly better results in counteracting injury than when it followed the bluestone treatment.

*Physiological studies of the effects of formaldehyde on wheat.* W. M. ATWOOD

The question of the actual entry of formaldehyde has been met and apparently answered in the affirmative by microchemical tests and by measurement of the imbibitional behavior of seeds in formaldehyde solutions. The principal studies so far have been directed towards a determination of the effects of formaldehyde of varying concentration upon the respiration of the wheat as measured by carbon dioxide output. Studies extending over two seasons seem to have established the fact that there is a marked depression of respiratory rates for wheat treated to formaldehyde at a concentration of one part to eighty parts of water. This depression in respiratory rate as compared with the check is apparent, though decreasingly so, with a lowering of the concentration just noted to 1–160, 1–240, and 1–320 the strength usually used in seed treatment. At 1–400 and 1–1000 the differences between checks and treated samples were not great enough nor sufficiently constant to indicate any marked effect on metabolism. Preliminary studies of the respiratory rates of seedlings from treated and untreated seed seem to show a marked effect of the formaldehyde in slowing down metabolism subsequent to germination. The studies will be continued the coming season.

*Relation of spore load to the per cent of stinking smut (Tilletia tritici).* F. D. HEALD

Artificial smutting was accomplished by adding 0.005 to 3 grams of smut to 100 grams of wheat. These amounts gave a spore load of 400 to 183,000 spores per grain. Maximum smutting was obtained with a spore load of 65,000–100,000 spores per grain. The spore load was determined by microscopic counts with a Levy cell. A spore load of 533 per grain produced 9.5 per cent of smut in Jenkin's Club, but a similar load for Marquis produced no smut. Farm infected seed planted in the spring does not smut

as much as winter wheat carrying an equivalent load. This study has made it possible to examine samples of wheat and predict with reasonable accuracy the amount of smut which might appear in the crop if no seed treatment is practiced. It has also shown that much spring wheat is treated when the spore load is so low as to give a negligible amount of smut.

*Observations upon the bacterial blight of field and garden peas in Montana.* HARRY MILLIKEN JENNISON

The most serious disease of seed peas grown in southwestern Montana is the bacterial blight caused by *Pseudomonas pisi* Sack. (*Ps* 211. 2322033). It is conservatively estimated that this disease was responsible for a 25 per cent reduction in the yield of the 1918 crop. This blight may be expected to be present and to cause more or less severe losses during any average summer. All parts above ground are subject to attack by the pathogene but special significance attaches to pod lesions since the seed are often contaminated in affected pods. Dissemination of the disease is thought to be due largely to contaminated seed. Under favorable weather conditions spread of the infection in the field is rapid and scarcely controllable. Differences in susceptibility to attack by the blight have been noted in about 40 varieties of garden and field peas. Alaska is one of the most susceptible.

*Bacillus atrosepticus van Hall, the cause of the blackleg disease of Irish potatoes.* HARRY MILLIKEN JENNISON

Frank isolated and described *Micrococcus phytophthorus* as the cause of black-leg of potatoes. More recently, at least four different "species" of *Bacillus* have been described as causing the disease in question, i. e., *Bacillus atrosepticus* by van Hall in Holland (1902) *B. phytophthorus* by Appel in Germany (1903) *B. solanisaprus* by Harrison in Canada (1906) and *B. melanogenus* by Pethybridge and Murphy in Ireland (1910).

The disease attracted the writer's special interest in 1913 when a study of it as it occurred in Montana was begun. During the next two years about forty isolations of the black-leg pathogen were made, with the idea of getting at the relationship of the parasite. Later subcultures of van Hall's, Appel's, Harrison's, and Pethybridge and Murphy's organisms together with the strains of the black-leg organism isolated in Maine were obtained. In 1915 an exhaustive study of the comparative morphology and physiology of the parasites was begun at the Missouri Botanical Garden. Twelve different strains selected from those above mentioned including those of the four authors referred, to earlier, were studied. These studies were largely completed without any knowledge of what Dr. W. J. Morse had done along similar lines and before the appearance of his paper in 1917. His studies of the "species" in question lead him to conclude that they are not specifically different. As a result of the writer's investigations it appears correct to conclude that the several strains studied are specifically identical, and because of priority van Hall's name should stand. A revised description of *Bacillus atrosepticus* van Hall yields the group number 221.1113033.

*The skin spot (Oospora pustulans) of the Irish potato.* F. D. HEALD

This disease recently studied in England was found in several car loads of Gold Coin potatoes shipped to the Spokane market from British Columbia. Ninety-five per cent of the tubers showed lesions. Young spots show as circular, brown spots a few mm. in diameter. With age they darken, appear slightly elevated but later slightly

depressed. Under conditions of abundant moisture the causal fungus sporulates in the old lesions. The fungus appeared identical with *Oospora pustulans* described as the cause of the skin spot in England. A quantity of tubers obtained for field test showed very poor keeping qualities. Many had the eyes killed by planting time and secondary invaders caused much deterioration. It has not yet been determined whether the disease will develop under Washington conditions.

*Collar rot on apple trees in the Yakima valley.* J. W. HOTSON
(Published in Phytopathology **10**: 465–486. *f. 1–15.* 1920).

*Heart-rot of prune and peach in Oregon* S. M. ZELLER

Many orchards of these stone fruits have been examined for heart rots. It has been found that in western Oregon a greater percentage of the existing wood decay in prune and peach trees is due to the pink-bracket fungus, *Trametes carnea* (Nees) Cooke than to all other fungi. Orchard surveys show that large pruning wounds are the most common place of infection. Two other fungi, *Lenzites saepiaria F.* and *Fomes pinicola* (Swen.) Cooke, which are also usually found on coniferous hosts very frequently cause heart-rot of peach and prune.

*A spur blight of pear caused by Botrytis.* S. M. ZELLER

During April and May specimens of blighted spurs of d'Anjou pear were sent in from two localities in Douglas Co., Oregon. The organism isolated from these spurs belongs to the cinerea group of Botrytis. Ten to 15 per cent of the spurs are damaged and some damage is reported on Winter Nelis and Comice pears.

*Some new hosts for the Rhizoctonia disease.* F. D. HEALD

This disease has been found in Klickitat County, Washington in serious form on young onions, in an affected field previously planted to potatoes. Numerous cases of the disease on strawberries have been studied from various parts of Washington.

*A Cytospora canker of apple and another "die-back" fungus of interest.* S. M. ZELLER

An apple canker due to a Cytospora which evidently is identical to that described by Stevens (U. of Ill. Exp. Sta. Bul. 217, 1919) occurs in various parts of Oregon. It infects living, but devitalized trees. *Cyphella marginata* McAlpine, previously reported on peach in Australia only, occurs on twigs of peach and almond in Benton and Douglas counties, Oregon.

*Moldy core of the Stayman Winesap.* F. D. HEALD

A study was made of the fungi found in the core cavities of Stayman Winesap apples in storage at intervals of two weeks during the winter period. Practically all apples with an open calyx canal showed a slight or a very evident growth of mold in the core. The forms isolated included two species of Penicillium, two of Alternaria, two of Cladosporium, and Hypochnus, and several species which failed to fruit in cultures. All forms failed to cause a rot in sound apples except the species of Penicillium and Alternaria. The conclusion is drawn that the presence of mold in the cores of Stayman Winesaps is no indicator of their keeping qualities, but the species that is present is the important factor.

*Report on pinon blister rust in California.* ELLSWORTH BETHEL and G. B. POSEY

No abstract furnished.

*Two new species of Sclerotinia.* B. F. DANA

The choke cherry in the Palouse country is attacked by a disease causing a leaf, twig and fruit blight. Young leaves are attacked early in the spring, and the disease often advances into the twig causing extensive blighting of the shoot. Affected leaves and shoots are covered with a gray, powdery Monilia. The fungus causing this disease is a typical Sclerotinia with the Monilia or parasitic stage on leaves and twigs, and the Sclerotinia or saprophytic stage on the fallen over-wintered fruits. The causal fungus is assigned to a new species, *Sclerotinia demissa.* Another Sclerotinia disease has been observed and studied on *Amelanchier cusickii.* This causes a leaf and fruit blight. Young or immature leaves are attacked, the margins rolling upward frequently making the leaf tubular. The Monilia stage appears on the inner protected surfaces of the rolled leaves. The diseased fruits dry up but remain hanging throughout the growing season. The fallen overwintering mummies produce large numbers of minute apothecia, 1–5 mm. in diameter. The causal fungus has been assigned to a new species, *Sclerotinia gregaria.*

*A new species of Exobasidium.* J. W. HOTSON.

This fungus attacks the young branches of *Vaccinium parvifolium*, apparently gaining access by some wound. The stem is slightly hypertrophied, and from this swelling spine-like processes grow out, which vary in length from 2 to 4 inches, occasionally longer. In the spring, about the middle of April in Seattle, or a little earlier in some seasons, numerous bright yellow branches which later become greenish and succulent, grow out all over the infected area. By the time they are fully developed they are pinkish at the tip. Sometimes as many as 75 to 100 of these branches appear on a single infection. As they get older they become perfectly white, due to the mycelium of the fungus growing over them. On this mycelium the basidia are formed and the large basidiospores are produced abundantly.

*Pathogenicity of Rhizoctonia and the fungus as a factor in crop production.* B. L. RICHARDS

Read by title.

*Soil temperature as a factor in influencing pathogenicity of Rhizoctonia with special reference to the potato.* B. L. RICHARDS

Read by title.

# REVIEWS

*An Introduction to Bacterial Diseases of Plants.* By Erwin F. Smith. xxx + 688 pp., 453 illustrations. Published by W. B. Saunders Company, Philadelphia and London, 1920.

There are many unique features about this new book. It is the first treatise of its kind, a product of the author's own researches, and it fills a need that was rapidly becoming urgent.

The subject-matter is arranged in five parts: I. A Conspectus of Bacterial Diseases of Plants, dealing with host-range, susceptibility, infection factors, incubation, recovery, agents of transmission, host-reactions, and other aspects of the science. II. Methods of Research, apparatus, culture media, technic of isolation, etc. III. Synopsis of Selected Diseases, in which the type, cause, technic, and literature for fourteen bacterial diseases are given, and for each disease so treated, a laboratory outline in the form of questions and suggestions is presented. IV. Miscellaneous, notes on additional diseases, suggestions for special study, the production of tumors in the absence of parasites, speculations on the chemical and physical stimuli underlying tumor-formation, and on the production of teratosis in the absence of tumors and of parasites. V. General Observations on experimentation, interpretation, ethics of research, and similar matters.

In a word the value of this handsome volume lies in the fact that its author is an authority on the subject. It may as well be admitted that many plant pathologists do not feel qualified to carry on research in this field, and so it is gratifying that the "father of the science of bacterio-phytopathology" has put into available form the results of his many years of experience. No one will question the validity nor the cogency of the contents of this volume, and its value is enhanced by the fact that the manuscript lay in a drawer for several years after it was first written, long enough that the author had forgotten its contents, which he then revised. This procedure, as many of us already know, is distinctive of all of Dr. Smith's contributions in his special field.

The style is easy and often tremendously interesting. The book is devoid of trite expressions, laborious sentences, and various other objectionable conventionalities. On the other hand, the reader will be delighted with the conversational phrases that are well placed throughout the book. The imperative mood is very effective because the author is in position to indulge in its use, which he does with discretion.

The reviewer must disappoint those who have not seen this book by omitting the statement that "the illustrations are poor." On the contrary, they are excellent when considered from all points of view. The enlargements of bacterial colonies should prove of great service to anyone who desires to make comparative cultural studies. The casual observer may be led to inquire whether the number is not excessive, but the teacher and student alike may find in each one an impressive lesson. Figure 104 is upside down, but this error is not chargeable to the author. Figure 14 may at first appear upside down, but the plant photographed was standing on its roots and is bent downward in order to bring the diseased portion into the field.

By custom, I am constrained to refer to the fact that the pages do contain some typographical and editorial errors, but the complete list would be short. A few mistakes which the beginner should know about follow: on page 474, number 14 should

read *Bacterium* instead of *Bacillus*, number 18 *marginale* instead of *aptatum*, number 34 *tabacum* instead of *tobacum*. on page 237, figure 179A exhibits gas-formation which contradicts a statement in the text (on pages 230–231).

The book fills the need of the teacher. While it is designed primarily for laboratory use, it also contains much valuable matter for supplementary reading. The suggestions given throughout are practicable—they have been thoroughly tried—and the hints on the details of technic, such as for isolating organisms, will prove serviceable. Bacterial Diseases of Plants (its short title) is adaptable to the use of either the graduate or undergraduate student. In a few cases fuller citations to literature would facilitate the work of the teacher. The investigator will find it an indispensible manual. Problems are pointed out at every turn, and on pages 474–477 is a list of fifty-one "larger problems." Some value could have been added to the book by the inclusion of a glossary of terms, especially for new or borrowed ones such as those used in the chapter on tumor-formation.

The discussion offered in part V is of special interest. Contained therein is much that we already knew but had not hitherto expressed. Both the beginner and the mature investigator will find an inspiration in these pages.

L. R. HESLER

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# PHYTOPATHOLOGY

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## THE RESISTANCE TO CITRUS CANKER OF CITRUS NOBILIS AND A SUGGESTION AS TO THE PRODUCTION OF RESISTANT VARIETIES IN OTHER CITRUS SPECIES

FORMAN T. McLEAN, and H. ATHERTON LEE[1]

WITH ONE FIGURE IN THE TEXT

Field observations upon the degree of citrus canker affection of the citrus species at Lamao, Philippine Islands, during the year 1917 revealed some interesting characteristics in regard to citrus canker infection of the horticultural varieties of the mandarin orange (*Citrus nobilis* var. *deliciosa*). These varieties usually showed a few cankers to each tree but the infections never became numerous and the trees were never seriously affected. The mandarin varieties have been considered by Wester (8, p. 156) to be truly resistant, and Stirling (5, p. 49) has made a similar statement for the Castalo tangerine; the junior author (3) has also presented such conclusions for the mandarin varieties. The observations and experiments here reported confirm this resistance. They also help to explain the nature of the resistance and suggest a means of utilizing it.

The infections upon the foliage of these varieties were in a great number of cases coincident with visible spine punctures or insect injuries. Since infection seemed to result only when the organism entered through some wound, the theory was formulated that the resistance of the mandarin varieties was due to some character of the epidermis. The following experiments were undertaken in an endeavor to test this hypothesis.

[1]For the laboratory facilities for this work the authors wish to thank Mr. Elmer D. Merrill, Director of the Philippine Bureau of Science. For the orchard facilities, thanks are also extended to Mr. Silverio Apostol, Chief of the Division of Plant Industry, Philippine Bureau of Agriculture, and Mr. F. G. Galang, Superintendent in charge of the Lamao Horticultural Station. Credit for the photographs is due the Philippine Bureau of Science.

An actively growing twig of Oneco mandarin was selected. The five leaves nearest the tip on this twig were coated on both upper and lower surfaces, with an infusion of *Pseudomonas citri* Hasse in tap water. This coating was made by drawing back and forth a platinum loop previously immersed in the infusion. The five leaves immediately below, on the same twig, were then coated in the same way and ten needle punctures made in each leaf through the coating of the infusion. After the inoculation moist cotton was placed around the twig bearing the inoculated leaves, and the whole twig was wrapped in strong waxed paper, to maintain a humid atmosphere around the inoculated leaves and to protect the infusion from being washed off by the intense rains. The results were: inoculations 1 to 5, without puncture, all negative; inoculations 6 to 10, each leaf with 10 punctures, all positive. As a preliminary test this corroborated the field observations very well. The experiment was therefore repeated several times on the Oneco variety, and also on the Canton mandarin, Kishiu, Szinkom, and a native seedling, using the same methods as in the preceding series unless otherwise noted. Inoculations 36 to 45 were control inoculations made on *Citrus maxima* to show the condition of the cultures of *Pseudomonas citri* which were used. They gave positive results.

### INOCULATIONS ON THE HORTICULTURAL VARIETY, ONECO OF CITRUS NOBILIS VAR. DELICIOSA

Inoculations 46 to 50 and 56 to 62 made on November 20, 1917, on both upper and lower surfaces of leaves without punctures; results, 46 and 47, one infection each, evidently at a wound; remainder negative.

Inoculations 51 to 55 and 63 to 70 made on November 20, 1917, on the upper surfaces of leaves each with 20 punctures; results, positive, except 63 and 70, where the leaves dropped off. Inoculations 56 to 70 are shown in figure 1.

Inoculations 96 to 101 made on December 5, 1917, on upper surfaces of leaves each with 20 punctures; results, 4 leaves 100 per cent positive, 2 leaves 95 per cent positive.

Inoculations 102 to 106 made on December 5, 1917, on both upper and lower surfaces of leaves without punctures; results, negative.

### INOCULATIONS ON THE HORTICULTURAL VARIETY, SZINKOM OF CITRUS NOBILIS VAR. DELICIOSA

Inoculations 21 to 25 made on November 19, 1917, on upper surface of leaves without puncture; results, all negative.

Inoculations 26 to 30, November 19, 1917, on lower surface without punctures; results, all but 29 negative; 29 positive, apparently because of insect injuries through which infection occurred.

Inoculations 71 to 73 and 79 to 83 on November 28, 1917, on both upper and lower leaf surfaces without punctures and not protected with paraffin paper; results, negative except for one canker.

Inoculations 74 to 78 on November 28, 1917, on upper surface of leaves with 20 punctures on each leaf and not protected with paraffin paper; results, from 5 per cent to 75 per cent positive.

FIG. 1. INOCULATED LEAVES 56 TO 70, "ONECO" ORANGE

Twig on left, leaves coated with infusion of *Pseudomonas citri* without wounding. Twig on right, leaves treated in same way but 20 punctures made in each leaf.

### INOCULATIONS ON THE HORTICULTURAL VARIETY, KISHIU OF CITRUS NOBILIS VAR. DELICIOSA

Inoculations 84 to 88 made on November 28, 1917, on the upper surfaces of leaves each with 20 punctures; results, 3 leaves 100 per cent positive and 2 leaves 95 per cent positive.

Inoculations 89 to 92 made on November 28, 1917, on both upper and lower surfaces of leaves without punctures; results, 3 leaves negative, 1 leaf dropped off.

Inoculations 107 to 111 made on December 6, 1917, on upper surface of Mandarin leaves each with 20 punctures, gave 100 per cent positive results.

Inoculations 112 to 116 on both upper and lower surfaces of Mandarin leaves without punctures were entirely negative.

To summarize: forty-eight leaves were inoculated without punctures on six different days during a period of two and one-half months, all but seven of which were negative—*i. e.*, Szinkom Nos. 29 and 72, Oneco Nos. 46, 47, 49, 50, and 105. Of the seven infected leaves three showed infections only at very evident wounds. Thus forty-one of the forty-five uninjured leaves showed no infection whatever. Two of these four infected leaves developed only one canker each, and on the other two the local character of the infections led to the belief that wounds were present although not visible to the unaided eye.

Inoculations 1 to 5 were made on the lower surfaces of unwounded leaves of grapefruit, *Citrus maxima* var. McCarthy, on November 19, 1917. Examination six days later showed 15 cankers in no. 2, 25 cankers in no. 3, 38 cankers in no. 4, 5 cankers in no. 5, and none in no. 1. This shows clearly the small proportion of infections on unwounded leaves of *Citris nobilis*, as contrasted with the large number of infections on a susceptible species such as *C. maxima*. These numerical data are not intended to prove the resistance of the mandarin varieties which is already generally recognized, but are presented as indicating the character of their resistance. Another series of inoculations was made on native seedlings of *Citrus nobilis*.

From table 1 it will be observed that the results without punctures do not show the same character of resistance for the native seedlings as the previous inoculations show for the recognized horticultural varieties of mandarin. This substantiates the field evidence which shows that the native Philippine mandarin orange trees, although varying in their susceptibility to canker, are in almost all cases more readily attacked than are the commonly propagated horticultural mandarin varieties.

The results of these experiments seem to warrant the following conclusions: (1) That the horticultural varieties of the mandarin orange (*Citrus nobilis* var. *deliciosa*) are truly resistant to citrus canker except when wounds permit the entrance of the causal organism. (2) That when punctures through the epidermis occur, these varieties give as large a proportion of positive results as do inoculations on *Citrus maxima* or *Citrus aurantifolia* (the most susceptible species). (3) Apparently, then, the epidermis is the structure which renders *Citrus nobilis* resistant to canker.

TABLE 1

*Inoculations on Philippine seedlings of Citrus nobilis, date of inoculations, January 4, 1918, date of observation of results, January 31, 1918.*[3]

| INOCULATION NUMBER | METHOD | RESULT |
|---|---|---|
| 151 | Upper and lower surfaces without punctures. | Shows 2 cankers |
| 152 | Do | Shows 2 cankers 1 at evident wound |
| 153 | Do | Many small infections at tip. |
| 154 | Do | Many small infections Many at evident wounds. |
| 155 | Do | No cankers. |
| 156 | Do | Leaf used by ants in making nest, lost for observation. |
| 157 | Upper surfaces only with 20 punctures. | 100% positive |
| 158 | Do | 90% " |
| 159 | Do | 100% " |
| 160 | Do | 90% " |
| 161 | Do | 100% " |
| 162 | Upper and lower surfaces without punctures. | Negative |
| 163 | Do | Do |
| 164 | Do | Do |
| 165 | Do | Do |
| 166 | Do | Do |
| 167 | Do | Do |
| 168 | Upper surfaces only with 20 punctures. | 80% positive |
| 169 | Do | 60% " |
| 170 | Do | 60% " |
| 171 | Do | 80% " |
| 172 | Do | 60% " |

A preliminary examination of the epidermis of resistant mandarin orange and non-resistant grapefruit leaves showed some differences, but none of these appear to explain the resistance. The structure of the epidermal tissues of *Citrus maxima* is much looser and the stomata are more numerous than those of *Citrus nobilis;* 38 stomata per square millimeter were found on *Citrus nobilis* and 50 per square millimeter on *Citrus maxima.*

The size of the stomata in these two species, however, was not found to be very different; the outside dimensions of those of a native form of *Citrus nobilis* are $17.5 \times 17.0$ microns and those of the native pummelo (*Citrus maxima*) are $20.0 \times 19.0$ microns. No apparent difference

[3]All of the inoculated twigs have been preserved as herbarium specimens and may be examined by any one interested in the results.

has been observed in the structure or size of the stoma such as would account for the exclusion of microorganisms of the size of *Pseudomonas citri*. Hasse (2, p. 99) gives the size of these organisms as 1.5 to 2.0× 0.5 to 0.75 microns.

Since the resistance appears to be confined to the epidermis, the authors propose that this fact be utilized in attempting to develop canker-resistant varieties of other Citrus species. It will be recalled that, in 1908 and 1909, Winkler (9), (10), (11), (12), working with species of Solanum succeeded in obtaining, by grafting, branches in which the tissues of two species were intermingled. These were of two types: one had sectors of the axis of different species and the other type had the separate layers of tissues of different species. These latter are termed periclinal chimeras or "graft hybrids" and those produced by Winkler all showed that the fruit character is controlled by the internal tissues, being little modified by the epidermis. Similar chimeras were also described by Baur (10), (1), with Pelargoniums. Sectoral chimeras (of the first type) have been produced repeatedly in Citrus, and have been perpetuated in Italy. These have been investigated quite thoroughly by Strasburger (6).

The second type has not been noted in Citrus, but the existence of several forms of sectoral chimeras leads to the belief that periclinal chimeras can be developed also, with epidermis of a resistant type of *Citrus nobilis* and the internal tissues of desirable varieties of *Citrus maxima*. Such dual structures exist in other woody chimeras as McFarlane (4, p. 268) has shown.

A periclinal chimera possessing the resistant epidermis of *Citrus nobilis* would appear to be protected from canker to the same degree as are the mandarin orange varieties of *Citrus nobilis*. The results of Winkler with Solanum indicate that the fruit characters would be controlled by the internal tissues and therefore would be very nearly like those of the *Citrus maxima* parent. The peculiar structure of citrus fruits does, however, modify this general statement somewhat. The pulp vesicles of the sections as shown by Tschirch and Oesterle (7, p. 303, pl. 70) are epidermal outgrowths of the walls of the section, and the membrane surrounding each vesicle is true epidermis, the juicy portion of each vesicle being of internal tissue. Thus the fruit of a chimera such as is proposed would probably have its texture but not its flavor modified by the character of the epidermal tissue. Since the known commercial grapefruit varieties are extremely susceptible, a periclinal chimera possessing the internal tissue of the grapefruit, with the epidermis of the mandarin, would appear to offer one solution to the problem of securing canker-resistant grapefruits.

SUMMARY

(1) Field observations on the occurrence of citrus canker on the horticultural varieties of *Citrus nobilis* var. *deliciosa* suggest that infections are in a large proportion of cases coincident with visible wounds.

(2) This conclusion was substantiated experimentally, the results showing that these varieties were fully as susceptible as the grapefruit varieties, when an entrance to the tissue was made for the parasite.

(3) The suggestion is presented that the periclinal chimera in which the epidermis is of *Citrus nobilis*, might confer resistance on other very susceptible but desirable Citrus species, while at the same time the character of the fruit would be but little changed.

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and
PHILIPPINE BUREAU OF SCIENCE

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# OBSERVATIONS ON WHEAT SCAB IN PENNSYLVANIA AND ITS PATHOLOGICAL HISTOLOGY

J. F. ADAMS[1]

WITH PLATES II AND III AND ONE FIGURE IN THE TEXT

The prevalence of wheat scab or Fusarium blight of wheat was early reported in this country by Weed (11) in 1890, Chester (3) in 1890, Arthur (1) in 1891, Hickman (5) in 1892, Selby and Manns (10) in 1909 and others. Chester (3) in Delaware states that it is a "serious disease and frequently occasions not more than one-half of a normal yield on account of the shriveling grain." Weed (11) in discussing wheat scab says: "In 1890 I saw a field of one hundred acres in Madison County, Ohio, considered the finest wheat field in the country, which was expected, shortly before harvest, to yield thirty-five to forty bushels per acre, so severely attacked by the disease that the yield was reduced to eight bushels per acre. Two other fields, one of twenty-five and the other of fifty, were shrunken in yield at least one-third." Arthur (2) in 1898 reported infection for Indiana ranging from 25 to 75 per cent. Johnson, Dickson and Johann (7) have recently reported infection ranging from a trace to fifty per cent for the Mississippi Valley and eastward.

As with the above reports on the prevalence of wheat scab the observations in Pennsylvania have been confined to the infection on the head. While no doubt seedling infection is a stage of the disease directly affecting the yield it has been impossible to ascertain the loss in this respect with any certainty. The highest estimate of scab infection in wheat fields under our observations has been 8 per cent. In 1917 the average infection for the state was estimated at 2 per cent. Since the average infection under our conditions involves such a small portion of the head the infection in the aggregate cannot be considered as a serious loss. It is conservative to state that the disease is present in all the wheat-growing centers of the state. Figure 1 indicates the distribution of wheat scab as shown by the plant disease survey reports for the state according to counties during the three-year period 1917–1920.

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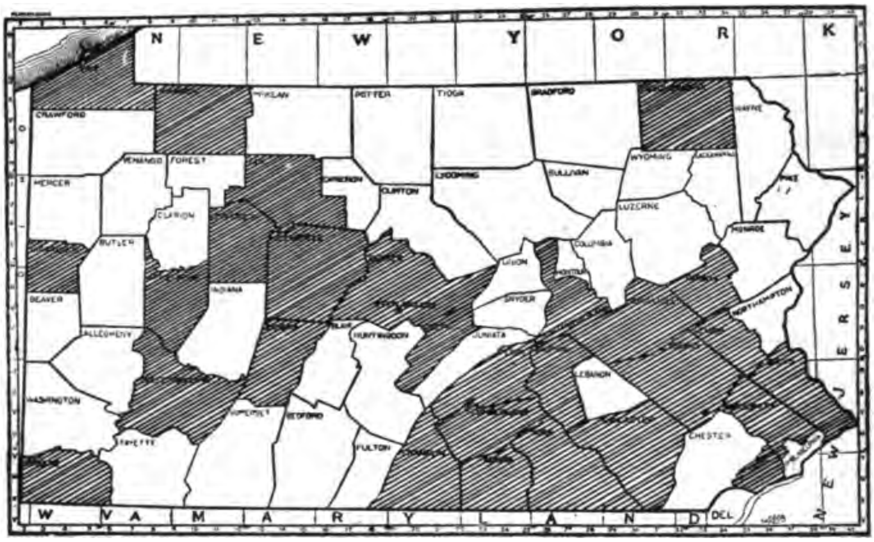


FIG. 1. Occurrence of wheat scab caused by *Gibberella saubinetii* in the counties of Pennsylvania during the years 1917 to 1920 is indicated by the crosshatching.

Field observations as reported by Hoffer, Johnson and Atanasoff (6) and others, as confirmed by our observations in this state, show a greater prevalence of wheat scab in fields where in crop rotation wheat has followed corn. One commonly finds on the old corn stubble in spring the fruiting bodies of *G. saubinetii* which no doubt are in part the source of inoculum. In some instances the fruiting bodies of *G. acervalis* are found associated with *G. saubinetii*. It is a common practice to only disk and harrow corn fields for sowing wheat in which case numerous stalks are exposed. In this way wheat seedlings as well as the head are subject to infection by the fungus on the exposed corn stalks. The loss through seedling infection is difficult to estimate, but our attention has not been called to any prevalent dying out in wheat fields where *G. saubinetii* could be attributed as the cause. Inoculations with this parasite on seedlings in moist chamber as well as in sterilized soil have established its virulent ability to kill seedling wheat.

Numerous predisposing factors have been reported favoring wheat scab infection. Weed (11) observed it as worse on weak growing varieties and those fields which are sowed latest. Hickman (5) states that defective drainage evidently increased the scab on the station farms and, in short, everything which tends to weaken the plant or retard its ripening renders it more subject to an attack. Arthur (2) observed that the attacks of the scab fungus were worse upon the late maturing than the early ones and certain French varieties were par-

ticularly susceptible. Selby and Manns (10) found that wheat scab was more severe on unmanured soil and on continuous planted areas. It was also determined that the scab fungus in the unfertilized plots destroyed an average of 5.9 per cent plants, while the fertilized plots showed 3.7 per cent. In rotation fields this loss was from 1 to 1.5 per cent. Mortensen (8) in his extensive review and studies of cereal diseases caused by Fusarium spp. states that "the dependence of the Fusarium attacks upon the weather conditions, damp air, and altogether abundant moisture favors without doubt the growth of the species of Fusarium and presumably all of these." He observed that infection was especially prevalent in wet years usually occurring between the time of flowering and maturing of the cereals.

Wheat scab infection as found under our conditions is usually restricted to one or two spikelets of the head. However, one occasionally finds the upper half or the complete head infected. I have first observed it in the "milk" or "setting" stage when the glumes of the infected spikelets appear as ripening prematurely. At this time it can be recognized by the chlorotic appearance of the glumes on infected spikelets. When the head is ripened the disease is not so easily recognized unless the fungus is fruiting abundantly. Weed (11) states that it is usually first noticed just as the heads are beginning to turn, when an examination of infested fields shows that with a portion of the heads the upper or lower half has prematurely whitened, leaving the rest green, the whitened part having on many of the glumes a more or less distinct or orange covering of the mycelium and the spores of the fungus. Detmers (4) reports that the whole ear may be diseased, but more commonly the upper, lower or central portion only is affected, and quite often the disease is confined to a single spikelet, the adjoining ones being apparently healthy.

The glumes of infected spikelets are usually closed and appear to be held together by the fungus growth within. In advanced stages of infection a considerable portion of the fungus growth is evident where the glumes overlap and in extreme cases the outer surface is covered with the interlaced mycelium. At the base of the glumes the superficial pink growth of the fungus is evident. Where a dense growth of the fungus is found it is most easily recognized by its dominant pink or salmon color. Upon separating the glumes of the infected spikelets one usually finds abundant superficial growth of the fungus. The kernel of wheat is conspicuously shriveled and often covered with a dense growth of mycelium usually white in appearance. Associated with the superficial fungus growth we find the typical spores of *G. saubinetii*.

Material of wheat scab from the West identified as caused by *G. saubinetii* is similar to our infection observed in Pennsylvania. With the severe outbreak of scab last year in the middle west a systemic infection of the head was common. Mr. H. W. Thurston, Jr., informs me that infection involving a half of the head is more common than under our conditions in Pennsylvania. Material with the perfect stage of *G. saubinetii* has been examined in which half the spikelets were infected and conspicuous with the black perithecia distributed over the glumes. We have not collected in Pennsylvania any material with the perfect stage of *G. saubinetii* fruiting on wheat.

All material which I have observed since 1914 in the state has shown that mature kernels were apparently infected, although it was commonly observed with some of the western scab that undeveloped ovules had become infected. Weed (11) states that the fungus apparently gains access to the tender undeveloped kernel. This difference is unquestionably dependent upon the time of infection.

The cause of wheat scab has been attributed to different species of Fusarium and Giberella by various investigators. The early references to wheat scab usually associated *Fusarium roseum* and *F. culmorum* as the cause. Wollenweber (12) has stated that *Giberella saubinetii*, *F. culmorum*, *F. subulatum* and *F. metochrorum* were formerly included in the collective species *F. roseum*. Owing to the early confusion in defining species of Fusarium and the similarity in signs of the fungus as described by various investigators, it is impossible to determine with certainty that *G. saubinetii* was the causal organism. Selby and Manns (10) were among the first in this country to prove conclusively the relation of *G. saubinetii* to wheat scab. These authors reported their cultures of *F. roseum* were identical with *G. saubinetii*.

Extensive culture work on this disease by Johnson, Dickson and Johann (7) has shown that three species are to be associated with this disease. "An extensive survey over fifteen states, correlated with an intensive survey over nine states in the winter-wheat area, brought out some pertinent facts with reference to the epidemic. A careful study of over one thousand specimens collected in fifteen states showed *Gibberella saubinetii* (Mont.) Sacc. to be the chief causal organism. Less than 1 per cent of the specimens yielded *Fusarium culmorum* (W. Sm.) Sacc., *F. Avenaceum* (Fr.) Sacc. and other Fusarium species."

Cultures of wheat scab from various sections of Pennsylvania have consistently identified *Gibberella saubinetii* as the cause. Typical conidia and absence of chlamydospores along with cultural reactions on cellulose and various sugar media have sharply differentiated this species from *G. acervalis* and *F. culmorum*. One strain of *G. saubinetii* which was

isolated from corn by Mr. F. G. O'Donnell has shown the tendency to produce perithecia, but no culture from wheat has developed perithecia.

The pathological histology of infected kernels has been given little study by previous workers. Chester (3) has stated "that a microscopic examination of the seed when badly shrunken shows it to be completely replaced by mycelium. The threads of this mycelium penetrate every portion of the grain, even to the germ, thus destroying its vitality." Arthur (1) reports that scab in wheat heads "is due to a minute fungus that attacks the wheat heads at the time of flowering. The spores of the fungus blow through the air, lodge on the delicate parts inside the flower and soon penetrate the kernel and envelope it with a mesh of moldy filaments which sap the life of the kernel and forming new spores spread the disease to other flowers throughout the field." Detmers (4) reported "the affected grain is very much shrunken and is covered externally by a thick white felted mass of mycelium of the fungus. On cutting open the kernel it is found to be hollow and filled with white mycelium." Weed (11) observed that "the kernels attacked by the fungus become mere shells covered inside and out with mycelium."

Material for study was obtained from infected ripened heads in the field. The shriveled kernels were soaked in water for twenty-four hours and then fixed for the same length of time in Petrunkewitsch killer. It was dehydrated by the usual method and kept in paraffin bath for forty-eight hours. Sections were cut 8 to 10$\mu$ in thickness and stained with Flemming's triple stain. Serial cross sections were made of infected kernels in order to determine the character of infection from the germinal end to the crown.

In infected as well as normal kernels the entire tissue of the pericarp or ovary wall is partly lacking since this in part becomes membranaceous and sloughed off with maturity of the kernel. The mycelium is found to have an extensive ramification throughout the kernel being intracellular as well as intercellular and all parts are penetrated. The integuments and nucellus were almost intact. The peripheral mycelium was often observed penetrating the cells making up the integuments. Typical appresoria-like bodies were formed as the means of intracellular penetration of the integumental cells, but this always appeared to be subsequent to the establishment of internal infection. The intracellular mycelium fills the cells like a number of haustoria and ramifies from cell to cell.

The nucellus was seldom disorganized and appeared to be the limiting factor in confining the fungus development within the seed. The

fungus evidently develops to the greatest extent within the limits of the nucellus.

All evidence would indicate that the fungus apparently gains entrance through the germinal end and after working inwards eventually develops towards the periphery. The development of the fungus in the glumes and cells external to the nucellus would seem to be subsequent to primary infection of the kernel.

In cross sections of infected kernels the protein or aleurone layer was found engulfed on either side by parallel strands of mycelium. This parallel mass of hyphae is most conspicuous between the nucellus and aleurone layer. The large cells making up the aleurone layer are early penetrated by the mycelium. These cells being rich in stored food seem favorable for abundant development of the intracellular mycelium. After the cellular contents are used up by the fungus the cells collapse and with advanced infection no evidence of the aleurone layer remains. The space usually occupied by this layer of cells is now replaced with extensive development of the mycelium. In some instances typical massing of the hyphae occur as shown in plate III, figures 3 and 4. These masses of interlaced mycelium have the appearance of incipient sporodochia although no mature ones were found developing spores. Their development was towards the periphery and approximate to the inner part of the nucellus.

No indication of the endosperm tissue was present in the infected kernels. The large storage cells for starch are not in evidence and in the space usually occupied by the storage cells only a loose irregular mass of starch grains remain as shown in plate III, figure 3. In some instances starch was found to be entirely absent. The complete disorganization and disappearance of the endosperm tissue establishes the evidence of a lysigenous effect subsequent to infection by this parasite. Long irregular branching hyphae are found in the endosperm cavity but not conspicuous as adjacent to the nucellus.

The most outstanding effect of this fungus is found at the germinal end in the embryo. The affinity this fungus has for the embryonic tissue is very striking and is well supported by the results secured with inoculations. There was no evidence of embryonic tissue in the infected kernels I have examined that were collected in the field, as it had been entirely destroyed as the result of infection. In the area usually occupied by the embryo there is found a compact mass of interlaced mycelium as shown in plate II, figure 2. How far the embryo was developed at the time of field infection could not be ascertained. However, with the size and development of other parts of the kernel as compared with normal kernels it would appear to have been ma-

ture. It is probable that infection becomes established first with the developing embryo since this is so favorable for the fungus development, and then spreads to the storage or endosperm tissue. As observed with the endosperm tissue the lysigenous effect on the embryonic tissue as the result of infection is very evident. It was also noted that the aleurone, nucellus and outer integuments in normal kernels were not as well developed for protection of the embryo as at other parts of the kernel.

The effect of this parasite on the glumes and rachis was very restricted; possibly associated with the greater cellular resistance. Cross sections of the glumes showed penetrating hyphae as well as disorganized cells. In some instances certain cells were filled with intra-cellular mycelium but not so extensively as with the kernels. Sections of the rachis showed very slight infection in the material studied. There were no indications that it progressed in this tissue from spikelet to spikelet.

Inoculation experiments were conducted to determine further the virulence of this fungus under artificial conditions. Durtz Longberry Red and Poole varieties were used in the experiments. The wheat was disinfected for three minutes in 1–1000 solution of $HgCl_2$ and then placed on moistened filter paper in sterilized chambers. Various lots of ten seeds after twenty-four hours and up to three days germination were removed to other sterile moist chambers, inoculated and kept under room temperature conditions of 22° C. In all inoculations mycelium was used as the inoculum from cultures of *Gibberella saubinetii* isolated from wheat scab and corn root rot. The mycelium was placed on the surface of the germinal end of the embryo and all results were positive.

There was no apparent difference as to susceptibility of seedlings up to three days' growth. Within a period of six days infection was so well established as to kill the embryonic tissue. The mycelium appeared to first become established in the embryonic tissue and then the entire kernel was involved with a profuse growth of mycelium. In cases where the plumule was two or three inches long it would collapse at the base and droop as a result of infection. The roots were attacked and covered with a growth of mycelium. Material at different stages of development was killed by the method already described. It was found that fungus infection developed most rapidly at room temperature. Inoculated kernels under temperature conditions of 8–10° C. retarded infection at least three days but eventually became established. This difference is associated with the low temperature favorable for germination and a higher temperature unfavorable

for growth of the fungus. Muth (9) observed less infection with *F. roseum* at 20° C. than with seeds at 30° C.

In the inoculated kernels the fungus becomes well established between the endosperm and scutellum. Plate II, figure 5, shows a portion of the palisade epithelium and scutellum storage tissue after the sixth day of inoculation. An entire cross section shows a weft of mycelium completely surrounding the scutellum. The epithelial cells are conspicuously plasmolysed and at a later stage the cells are penetrated and the tissue disorganized. Plate II, figure 5, shows the progress of the fungus at the end of six days in its characteristic massing of mycelium between the nucellus and aleurone layer as observed with the infected kernels from the field.

The root system is as severely attacked as the embryo. The cortical tissue as well as the stele appears to offer no resistance to the extensive ramification of the fungus. In cross sections of secondary roots the stele was found completely disorganized and replaced with strands of parallel hyphae.

Disinfected wheat after 48 hours in moist chamber was inoculated as previously mentioned and planted one-half inch in depth in sterilized soil. The same varieties of wheat were used as in the moist chamber inoculations. They were watered each day with distilled water and kept under room temperature conditions and exposed to window light. The control pots showed normal growth for the period of eighteen days at which time the plumules or seed leaves in the inoculated pots had died down. Good growth was made for the first four days in the inoculated pots but then appeared to gradually weaken and were finally killed. Examination of the seedlings showed the same disorganization of tissue as observed with the inoculations in moist chambers. The only difference noted was the interval of time with respect to the establishment of infection which would suggest that under soil conditions the infection period is prolonged several days due to lower temperature.

The evidence from inoculation experiments under these conditions fully supports the results observed with infected material under field conditions. As a further check inoculations were carried out on wheat heads in the "flowering" and "milk" stage. The inoculum used was the same as with the seedlings and placed on one or two spikelets of a head and the entire head protected in a glassine bag. At the end of twelve days the heads were cut and examined. Positive infection was secured in all but three inoculations of thirty heads infected. The infection in every instance was confined to the point of inoculation. There was no indication of its spreading throughout the head. Infections in the flowering stage showed the young ovules never matured


CROSS SECTIONS OF NORMAL AND DISEASED WHEAT GRAINS

but were reduced to a small shriveled mass consisting for the greater part of mycelium. There was no conspicuous growth of superficial mycelium inside or upon the glumes. The infected spikelets appeared similar to the condition called "blasting of heads." Infection in the milk stage produced shrivelled kernels as found under field conditions. The shrivelled kernels and the glumes were covered with a conspicuous development of mycelium. The embryo was found disorganized as observed under conditions of natural infection in the field.

## CONCLUSIONS

Wheat scab in Pennsylvania has been observed to be most prevalent as an infection of the head. While seedling infection is no doubt a serious phase of the disease it is probable that soil and temperature conditions with the planting of wheat in the fall are not conducive to seedling infection.

Wheat scab is more serious in fields following the planting of corn and the evidence is quite convincing that in part the source of inoculum comes from the development of *G. saubinetii* on corn stalks.

Observations of infected and inoculated kernels indicate that the fungus if once established will destroy the embryo.

Inoculation experiments support the evidence that under favorable conditions *G. saubinetii* may become a virulent parasite of wheat seedlings.

A study of infected kernels from various parts of the state collected at the time of harvesting indicate that the prevalent type of infection occurs after the flowering stage.

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PLATE II. CROSS SECTIONS OF NORMAL AND DISEASED WHEAT GRAINS

Fig. 1. Photomicrograph of a cross section of a normal wheat kernel through the germinal end. This illustrates the normal appearance and position of the pericarp, aleurone, endosperm and embryonic tissue.

Fig. 2. Photomicrograph of a cross section through the germinal end of a wheat kernel infected with *Gibberella saubinetii*. The complete disorganization of the above mentioned tissues is in sharp contrast. The aleurone layer and endosperm tissue is completely disorganized. The embryonic tissue is practically replaced by an interlaced mass of mycelium. No evidence of the scutellum is to be found.

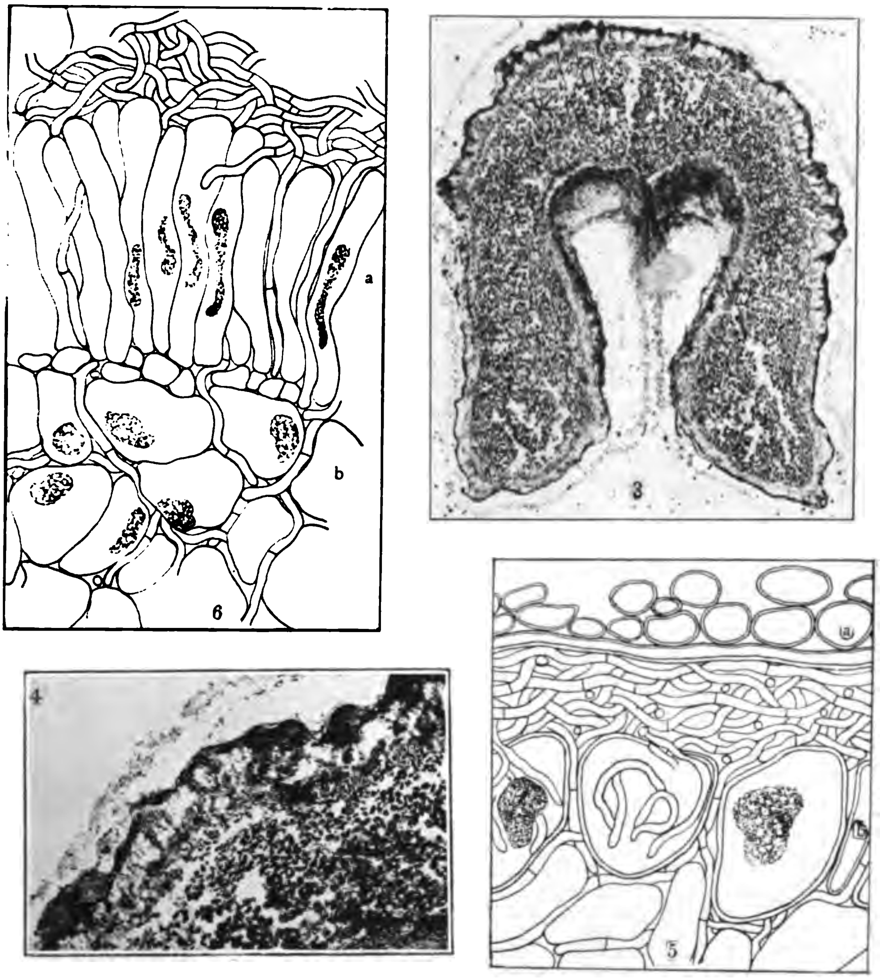
PLATE III. HISTOLOGY OF WHEAT SCAB.

Fig. 3. Photomicrograph of a cross section above the germinal end of a wheat kernel infected with *Gibberella saubinetii*. The endosperm tissue and aleurone layer appear the same as in figure 2.

Fig. 4. Photomicrograph showing an enlarged view of a portion of the periphery of figure 3. The large dark globular masses are the sporodochia which originate between the nucellus and aleurone layer.

Fig. 5. Portion of the periphery of a kernel six days after inoculation with *G. saubinetii*. The contents of the aleurone layer have collapsed and the two cells on the left show penetration of the mycelium. The extensive development of the mycelium is shown as it developed like a wedge between the nucellus (a) and the aleurone layer (b). It is in this area that the sporodochia originate.

Fig. 6. Showing portion of the scutellum after six days inoculation with *G. saubinetii*. The mycelium develops extensively between the palisade of epithelium and the endosperm and then becomes established in the storage tissue of the scutellum. The mycelium is at first intercellular and the host cells are plasmolysed but later the mycelium becomes intracellular causing complete collapse of tissue. a-palisade epithelium, b-parenchyma storage cells of scutellum.




HISTOLOGY OF WHEAT SCAB

# EXPERIMENTAL DATA ON LOSSES DUE TO CROWN-CANKER OF ROSE

L. M. MASSEY

Some observations and experimental data concerning the pathogenicity of *Cylindrocladium scoparium* Morgan, the cause of crown-canker of rose, have been recorded by the writer in a former publication.[1] Statements based principally on observations and on reports of growers were made to the effect that diseased plants do not die quickly but linger on and yield increasingly poor and few blossoms; that they do not respond to heavy applications of fertilizers as do healthy plants; that the number of plants actually killed within the duration of time they are kept by growers is very small, but that the normal activities of the plant are so materially interfered with that they can be grown only at a financial loss; and finally, that *C. scoparium* is a fungus low in parasitism and that conditions of moisture are important factors in its development.

Since mortality can not be used as an index of the financial loss occasioned by this disease, it seemed desirable to determine by experimentation the nature and the extent of the losses. Some data indicative of the nature of the injury have been obtained in an experiment extending through three years' time. Incidentally, other facts relative to the pathogene and to experimentation under greenhouse conditions have been obtained, and are here set forth.

The house in which the plants were grown was of modern construction equipped with side and over-head ventilators. No roses had ever been grown in it. There were three solid beds, constructed of concrete, each 21 feet in length, the two outside ones being 4 feet in width (inside measurements), and the middle one 5 feet. The walls of the beds were 4 inches thick. The sub-soil in these beds was a mixture of sand and gravel. The soil obtained for growing the plants was composed of 4 parts of heavy sod composted with 1 part of manure. Before placing the soil in the beds well-rotted cow-manure was added in the proportion of one to three, mixed thoroughly and the mixture steam-sterilized. The steaming was done in a bed 4 feet in width, by placing the soil in a 12-inch layer over 4 perforated pipes running

[1]Massey, L. M. The crown canker disease of rose. Phytopathology 7: 408–417. *3 fig.* 1917.

lengthwise of the bed. During the treatment the soil was covered with canvas. About five pounds pressure was maintained in the pipes, and the treatment lasted three hours. The house was steam-heated, the pipes carrying the steam being hung on the side walls about 16 inches removed from each of the two outside beds.

A total of 221 plants was used in the experiment, 68 of which were planted in each of the two outside beds, and 85 in the middle bed. They were of the variety Ophelia, grafted on Manetti stock.[2] As the plants increased in size following their receipt on March 1, 1917, they were shifted to 3-inch and later to 4-inch pots, using stem sterilized soil, and finally on May 21, 1917, to the beds containing the steamed soil. The beds were then divided into four sections, each, by means of new hemlock boards measuring 1 inch in thickness and 12 inches in width. The boards were sunk into the soil to a depth of about 10½ inches. The sections, with the number of plants in each, are indicated in table 1. Each of the sections A to C, and J to L, inclusive, contained 20 square feet; sections D and I, 24 square feet each; sections E, G and H, 25 square feet each; and section F, 30 square feet. The plants were 10 inches apart, crosswise of the bed, and 14 inches apart, lengthwise.

Cultural studies had given no indication of sensitiveness of the fungus to either acid or alkaline media. It was thought, however, that possibly the addition of certain chemicals to the soil might exert some influence upon infection by the pathogene, either through toxic action, by changing the acidity of the soil, or indirectly through their effect on the host. Consequently on July 17, 1917, the following chemicals were applied in the stated amounts per square foot to the indicated sections (see table 1): section A, calcium sulphate,[3] 0.1 pound; section B, potassium sulphate, 0.1 pound; section C, ammonium sulphate, 0.025 pound; section D, acid phosphate, 0.5 pound; section L, stone lime, 0.2 pound. Sections E to K received no chemicals. The dry chemicals were sprinkled over the soil, and worked in with a surfacer. On the following day the soil was well watered.

On July 20, 1917, the soil in sections A to D and J to L was inoculated as follows: Six-weeks-old cultures of *C. scoparium* growing on potato-agar in Erlenmeyer flasks of 300 cc. capacity were thoroughly mixed with a small quantity of equal parts of corn-meal and sand. A handful of this mixture was placed in the soil near, but not in contact with, each plant. An attempt was made to add approximately equal quantities of inoculum in each case. The inoculum was then

[2] The writer wishes to express his appreciation of the kindness of A. N. Pierson, Inc. of Cromwell, Connecticut, in furnishing *gratis* the plants used in this experiment.

[3] The chemicals, calcium sulphate, potassium sulphate, and ammonium sulphate, were chemically pure.

TABLE 1

*Arrangement of beds and sections, and the relative positions of rose plants in each. The figures indicate the relative positions of the plants and the number of blossoms produced by each during the third season. Starred letters indicate sections containing infested soil, starred figures indicate the plants from which successful isolations of the fungus were made.*

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 45 | 42 | 40 | 27 | 37 | 37 | 37 | 26* | 18* | 24* | 27* | 21* | 27* | 31* | 19 | 19 | 23* |
| 34 | 29 | | 27 | 23 | 24* | 9* | 16* | 9* | 19* | 21* | 22* | 25* | 14* | 26* | 11* | 27* |
| 40 | 33 | 29 | 36 | 20 | 19* | 34 | 14* | 10* | 26* | 27 | 17 | 14 | 15* | 19* | 21* | 35 |
| 59 | 37 | 43 | 42 | 30 | 44* | 27* | 13 | 26 | 28* | 23 | 29* | 22* | 25 | 24 | 31 | 21 |
| | | I | | | | J* | | | | K* | | | | L* | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 19 | 27 | 41 | 21 | 23 | 24 | 36 | 53 | 43 | 34 | 33 | 34 | 39 | 43 | 34 | 49 | 39 |
| 37 | 23 | 26 | 19 | 20 | 30 | 41 | 33 | 22 | 40 | | 38 | 31 | 19 | 16 | 22 | 31 |
| 28 | 24 | 31 | 25* | 26 | 39 | 19* | 43 | 30 | 20 | 48 | 26 | 37 | 46 | 25 | 30 | 33 |
| 26 | 26 | 18 | 24* | 28 | 31 | 7* | 28 | 30 | 15 | 28 | | 39 | 31 | 23 | 31 | 15 |
| 29 | 36 | 24 | 28 | 34 | 46 | 41 | 43 | 35 | 32 | 49 | 36 | 42 | 34 | 37 | 49 | 29 |
| | E | | | | | F | | | | G | | | | H | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32* | 17* | 20* | 23* | 22* | 24 | 32 | 23 | 29* | 22 | 18* | 25* | 17 | 22 | 23* | 20* | 18* |
| 18 | 9 | 9* | 10* | 13* | 18* | 27* | 16* | 15 | 19* | 27* | 24 | 22* | 16* | 23* | 21* | 21 |
| 16* | 35* | 17 | 16* | 18 | 22* | 21 | 31* | 21* | 28 | 24* | 24 | 20 | 21* | 23* | 23* | 18* |
| 17* | 25* | 16* | 23* | 29 | 33 | 21* | 29 | 28 | 27 | 23* | 29* | 22 | 26* | 21* | 28* | 24* |
| | A* | | | | B* | | | | C* | | | | | D* | | |

mixed with the upper inch or so of soil, with the aid of a surfacer, and the soil well watered. The above procedure was duplicated on January 11, 1918. Sections E to I received no inoculum.

No attempt was made to control the time of cropping by "pinching" the buds. Otherwise the methods used in handling the plants approximated those of commercial growers. The temperature of the house was held at 65° F. during the day, and 60° F. at night. The plants were rested during the summer by withholding water for about six weeks, beginning the middle of June. During the last week of July, just prior to the resumption of watering, the plants were cut-back, and the upper 3 inches of soil replaced by a mixture of soil and well rotted cow-manure in equal amounts, to which was added a small quantity of bone meal. In January and again in March of each year a top-dressing of well rotted cow-manure about 2 inches in thickness was evenly distributed over all three beds. The moisture content of the soil was not controlled. An effort was made, however, to keep the soil in all sections as uniformly moist as possible by the ordinary means at the disposal of a commercial grower, and as moist as was consistant with good growth. Although care was exercised to see that no soil was carried from one section to another, it is doubtful if the precautions taken were sufficient to entirely prevent this possibility, the sections being separated merely by thin boards. It is indeed surprising that, as indicated by culture studies (see page 129), but four of the plants growing in presumably uninfested soil became diseased.

Little black-spot (*Diplocarpon rosæ* Wolf) appeared in the house during the three seasons. This disease, together with mildew (*Sphærotheca pannosa* (Wallr.) Lév. var. *rosæ* Wor.) which appeared at various times during each winter, was readily controlled by dusting the plants with a mixture of 90 parts finely ground sulphur and 10 parts of arsenate of lead. Upon the appearance of either black-spot or mildew, all of the plants were immediately dusted. Three or four applications of dust made at weekly periods, together with the judicious use of water and the regulation of the temperature, were sufficient to control the diseases in all cases.

During the first season (winter of 1917–1918) no record of blossoms produced by the plants was taken. On December 13, 1917, the soil was pulled away from the crown of each plant in an attempt to determine whether or not the disease was present. In many instances there were unmistakable symptoms of infection; in other cases it was impossible to determine whether the darkening and checking of the tissues at the crown were due to disease or to the normal habit of the plant. Consequently no record of any value could be made.

During the season of 1918–1919 a record was taken of the number

of blossoms produced by the plants in each section, but not from individual plants, as was done during the season of 1919–1920. The records are shown in tables 1 and 2. Throughout the three years in which the plants were grown not a single plant died from crown-canker or any other cause. Three plants, the locations of which are indicated by blank spaces in table 1, developed crown-gall. No record was made for these plants.

The experiment was terminated on June 1, 1920. At this time, after removing the plants from the soil, tissue plantings from the crown of each plant were made in sterilized potato-agar with the idea of determining whether or not the fungus was present in the tissues. In making these cultures the following procedure was employed: The crown-segments of the plants were first washed thoroughly by holding them in running water under the tap and scrubbing with a stiff brush. The outer bark was then scraped away and the segment immersed in 50 per cent alcohol for three minutes, and then in 1–1000 mercuric chloride solution for ten minutes. Following this the segment was rinsed in 95 per cent alcohol which in turn was removed by flaming. Bits of tissue were then removed with a flamed scalpel and placed in sterilized potato-agar in previously poured Petri dishes. Eight plantings were made from each plant.

TABLE 2

*Record of the number of rose plants and the total and average number of blossoms produced by plants growing in infested and uninfested soil during the second and third seasons. The starred letters indicate sections containing infested soil*

| SECTION | NUMBER OF PLANTS | TOTAL BLOSSOMS | | AVERAGE BLOSSOMS PER PLANT | |
|---|---|---|---|---|---|
| | | 1918–1919 | 1919–1920 | 1918–1919 | 1919–1920 |
| A* | 16 | 586 | 303 | 36.62 | 18.94 |
| B* | 16 | 510 | 379 | 31.87 | 23.69 |
| C* | 16 | 465 | 383 | 29.06 | 23.94 |
| D* | 20 | 586 | 429 | 29.30 | 21.45 |
| E | 20 | 760 | 532 | 38.00 | 26.60 |
| F | 25 | 945 | 805 | 37.80 | 32.20 |
| G | 18 | 686 | 621 | 38.11 | 34.50 |
| H | 20 | 803 | 636 | 40.15 | 31.80 |
| I | 19 | 820 | 673 | 43.16 | 35.42 |
| J* | 16 | 550 | 363 | 34.37 | 22.69 |
| K* | 16 | 519 | 372 | 32.44 | 23.25 |
| L* | 16 | 613 | 361 | 38.31 | 22.56 |
| All Sections | 218 | 7843 | 5857 | 35.98 | 26.87 |

The plants from which *C. scoparium* was isolated are indicated in table 1. Severe measures to insure thorough surface sterilization were made necessary by the heavy infestation of the soil; and since the fungus frequently does not penetrate deeply into the tissues—in many cases probably not beyond the bark—too much emphasis should not be placed upon successful isolations as criteria of disease. It is obvious, however, that the results obtained warrant a certain amount of confidence in their value. Successful isolations of the fungus were obtained from 77 of 116 plants growing in infested soil, and from but 4 of 102 plants growing in supposedly uninfested soil. These results, especially when correlated with the production of blossoms (see page 132), are significant in indicating the high percentage (66.38 per cent) of infected plants from infested soil, as well as indicating no small amount of accuracy relative to the isolation methods used. No certainty exists, considering the strenuous treatment given to insure surface sterilization, that the fungus was isolated from every diseased plant. Consideration also should be given to the possibility of the fungus having died after penetrating and killing certain tissues of the host. Plants referred to in the following paragraphs as being diseased are those from which successful isolations of the fungus were made.

Cankers due to *C. scoparium* other than those formed at the crown of the plants were relatively uncommon in the house throughout the duration of the experiment. Occasionally the stubs left in cutting the blossoms were attacked by the fungus, but in no great number of instances did the pathogene work into the stem to any appreciable distance. These results are contrary to the statements of several growers, who claim that the fungus is rapidly and easily disseminated to parts of the plant above the soil resulting in material quantities of dead shoots. That the above-ground parts of plants were attacked in so few instances together with the fact that only four of the plants in the presumably uninfested soil were attacked at the crown, may be due to the existing sanitary conditions of culture. Great care was exercised by the gardener in preventing the mixing of the soil in the various sections and the accumulation of dead plant-parts.

The growth of grafted plants in solid beds is not conducive to the production of shoots from parts beneath the soil. In the few instances, however, where such shoots were formed by plants growing in infested soil, these shoots were early attacked and killed by the fungus. On the other hand such shoots formed by plants in uninfested soil remained healthy.

### DISCUSSION OF RESULTS

As stated above, the records for 1918–1919 consisted of the number of blossoms cut from each section. These are given in table 2. From 116 plants growing in infested soil, a total of 3829 blossoms, or an average of 33.01 per plant were obtained, whereas 102 plants in uninfested soil produced 4014 blossoms, or an average of 39.35 per plant. This difference of over six blossoms per plant would determine in a large measure whether or not such plants could be grown at a profit (see page 133). As to whether or not the chemicals added to the soil were of any influence during the second season, or were instrumental in affecting the yields is problematical. As pointed out by Muncie[4] applications of potassium sulphate and of lime decrease, and of acid phosphate increase the yield. It should be noted that the plants in section D to which acid phosphate was added gave an average of 29.30 blossoms, while those in section B to which potassium sulphate was added, and in section L to which lime was added, gave an average of 31.87 and 38.31 blossoms, respectively. The variety Ophelia may differ from the varieties Richmond, Killarney and Bride, as used by Muncie, in its response to the chemicals in question; or possibly the conditions under which Muncie worked were not comparable to those of the experiment of the writer. Unless these differences exist there is evidence that no effect was exerted by chemicals during the period covered by these records. It would seem that the factor directly responsible for this reduction is that of disease.

Doubtless more importance is to be attached to the results for the season of 1919–1920, during which the record of the production of blossoms by individual plants was taken. The positions of the plants in the beds, and the number of blossoms produced are indicated in tables 1 and 3. In table 2 a comparison by section is made of the yields of 1918–1919 and 1919–1920. During this third season a total of 5857 blossoms were cut from the 218 plants, of which 4117 were obtained from 137 healthy plants and 1740 from the 81 plants from which the fungus was successfully isolated. The healthy plants thus averaged 30.05 blossoms, and the diseased, 21.48, per plant.

Since, as stated above, the success or failure of isolation of the fungus from plants may have been of doubtful value as a means of determining whether or not a plant was diseased, it seems advisable to compare the yields of the plants growing in uninfested soil with those growing in infested soil. The 116 plants growing in infested soil produced 2590

[4] Muncie, F. W. The use of commercial fertilizers in growing roses. Illinois Agric. Exp. Sta. Bull. 196: 510–564, *2 fig.* 1917.

blossoms, or an average of 22.33 per plant; the 102 plants growing in uninfested soil yielded 3267 blossoms, or an average of 32.03 per plant. These results are probably the most striking of any obtained, the reduction of blossoms being obviously due to the single factor of infested soil. This difference, as indicated by sections, may be seen in table 3. Thirty-nine supposedly healthy plants in infested soil produced 925, or an average of 23.72 blossoms per plant; 77 supposedly diseased plants in infested soil gave 1665, or an average of 21.62 blossoms per plant. Thus there is strong evidence that the supposedly healthy plants were affected by some factor, the most obvious one being the presence of the fungus in the soil. This evidence is further strengthened by the fact that 98 healthy plants growing in the presumably uninfested soil produced 3192 blossoms, an average of 32.57 per plant, whereas the 4 diseased plants in this soil yielded 75 blossoms or an average of 18.75 per plant. The reduction of about 10 blossoms per plant which must be attributed to the presence of the fungus in the soil, with the resulting infection of the plants, is more than sufficient to determine whether or not diseased plants can be grown at a profit.

TABLE 3

*Record of the number of diseased and healthy rose plants showing the total and average number of blossoms produced during the third season. Starred letters indicate sections containing infested soil*

| SECTION | NUMBER OF PLANTS | NUMBER OF FLOWERS | NUMBER OF DISEASED PLANTS | NUMBER OF FLOWERS | | AVERAGE NO. OF FLOWERS | |
|---|---|---|---|---|---|---|---|
| | | | | DISEASED PLANTS | HEALTHY PLANTS | DISEASED PLANTS | HEALTHY PLANTS |
| A* | 16 | 303 | 13 | 259 | 44 | 19.92 | 14.67 |
| B* | 16 | 379 | 8 | 170 | 209 | 21.25 | 26.12 |
| C* | 16 | 383 | 9 | 215 | 168 | 23.89 | 24.00 |
| D* | 20 | 429 | 15 | 327 | 102 | 21.80 | 20.40 |
| E | 20 | 532 | 2 | 49 | 483 | 24.50 | 26.83 |
| F | 25 | 805 | 2 | 26 | 779 | 13.00 | 33.87 |
| G | 18 | 621 | .. | ... | 621 | .... | 34.50 |
| H | 20 | 636 | .. | ... | 636 | .... | 31.80 |
| I | 19 | 673 | .. | ... | 673 | .... | 35.42 |
| J* | 16 | 363 | 11 | 216 | 147 | 19.64 | 29.40 |
| K* | 16 | 372 | 12 | 291 | 81 | 24.25 | 20.25 |
| L* | 16 | 361 | 9 | 187 | 174 | 20.79 | 24.86 |
| All sections | 218 | 5857 | 81 | 1740 | 4117 | 21.48 | 30.05 |

Reference to table 2 will show that in all cases fewer blossoms were produced by the plants in each section during 1919–1920 than during 1918–1919. Undoubtedly part of this reduction was due to the aging of the plants. The average decrease per plant for those growing in infested soil was 10.68, while for those growing in uninfested soil the average decrease was 7.32 blossoms per plant. The decrease in the number of blossoms from the plants in uninfested soil is significant as indicating the normal reduction in yields of plants carried into the third year, while 3.36 blossoms per plant represents the decrease over and above the normal decrease, due to the parasite. This slight increase over the normal reduction may be taken as evidence that the fungus had not advanced much further into the tissues during the last year that the plants were carried.

Few figures are available from which to determine the cost of the production of blossoms or to indicate the margin of profit on which commercial growers carry their plants. Trade journals in which the prices of blossoms are given show that the returns to the grower from Ophelia roses vary from two to sixteen cents each, with even higher values at certain times of the year. A fair average value per blossom to the grower is about ten cents. On this basis, a reduction of ten blossoms per plant, which as shown above, must be ascribed to the influence of the parasite, would mean a loss of one dollar per plant per season, for plants growing in soil infested with the fungus. Obviously this loss must be deducted entirely from the profits of the grower, for the cost of growing diseased plants would be the same as that for healthy plants. Consideration must also be given to the failure of diseased plants to respond to forcing during periods when there is the greatest demand for blossoms, and consequently the highest returns to the grower. Although no figures are at hand it is probable that blossoms from diseased plants are of inferior quality, in that the stems are shorter. Certainly the average grower does not sell blossoms at a sufficiently large margin to enable him to realize a profit on plants which are producing ten less than the normal number of blossoms.

Although the number of plants used in the experiment is not large, it is felt that the results amply justify all of the conclusions that are drawn from them. The house was small and the heating system so constructed and arranged that definite and even temperatures could be maintained throughout. Since the heating pipes were next to the two outside beds it is probable that the temperature of the soil and that of the air surrounding the plants in these beds was slightly higher than corresponding temperatures of the middle bed. However, the plants in each section of the two outside beds were subjected to the same con-

ditions, and since one section was a check, any differences due to uneven temperatures are evident from the data presented. The soil was thoroughly mixed before being placed in the beds, to ensure uniformity, thus eliminating the factor of soil variation. A method of maintaining a constant moisture content of the soil would possibly have helped to eliminate this varying factor, but it is doubtful whether or not the slight variation which occurred in the sections was sufficient to influence the results.

## SUMMARY

1. The data here presented were obtained from an experiment conducted throughout a period of three years. Ophelia roses were grown under glass in infested and uninfested soil, and a record taken of the number of blossoms produced under these conditions. The losses caused by *Cylindrocladium scoparium* Morgan were measured by the reduction in the number of blossoms.

2. Losses are to be measured by the decrease in yields of blossoms and not by the death of the host.

3. Calcium sulphate, ammonium sulphate, potassium sulphate, acid phosphate and lime under the conditions of the experiment exerted no influence on the losses caused by the parasite.

4. A decrease of about 10 blossoms per plant represents the annual loss when plants are grown in infested soil. This reduction means a loss to the grower of at least one dollar per plant.

5. Mildew and black-spot were readily controlled by three or four applications of sulphur-lead dust, made at weekly periods, combined with judicious regulation of water and temperature.

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# A LOTUS LEAF-SPOT CAUSED BY ALTERNARIA NELUMBII SP. NOV.

Ella M. A. Enlows, and Frederick V. Rand.

With Plate IV and One Figure in the Text

This leaf-spot disease was first observed by Rand in the summer of 1913 at Kenilworth, D. C., and in autumn of the same year at the New York Botanical Gardens on leaves of Egyptian lotus (*Nelumbium speciosum*). From the general character of the disease it was thought to be of parasitic origin, and in the summer of 1914 the authors began a joint investigation of the cause.

Since 1913 the disease has been seen by both of us at Riverton, N. J., again at the New York Botanical Garden and Kenilworth, D. C., and by Rand at Arlington, N. J., and Pittsburgh, Pa.

## DESCRIPTION OF THE DISEASE

The disease begins as very small, smooth, reddish brown flecks, which increase in size until 5 or 10 mm. in diameter. They may be roundish or somewhat irregular in form with a tendency toward the formation of concentric bands of alternately lighter and darker brownish tissue (Plate IV A). The margin is definite. In some cases the spots are surrounded by a lighter green halo. When the spots are very numerous many of them coalesce, and the leaf gradually dries and curls from the margin inward.

## ISOLATION OF THE FUNGUS

On July 22, 1914, diseased material was collected at Arlington, N. J., and the Brooklyn Botanical Garden, New York City. Free-hand sections from these leaves showed the presence of brownish septate mycelium and plates were poured in the usual manner, using corn-meal agar. The majority of the colonies coming up on these plates consisted of but one type of fungus (Isolations R214 and R218). The mycelium was brownish, septate and similar to that observed in the free-hand sections of the diseased leaves. In less than a week abundant spores of the Alternaria type had developed on these colonies. During the years 1914 and 1918, inclusive, 23 isolations were made by both authors from material from the Brooklyn Botanical Garden, New York City, Arlington and Riverton, N. J., Kenilworth, D. C., and from articially inoculated plants growing in the greenhouse. The same type of fungus was obtained in all these isolations, and all were proved to be infectious by inoculation into healthy plants from pure cultures.

INOCULATIONS

The first inoculations were made on August 8, 1914, in the following manner (Isolations R214 and R218): Leaves of lotus with petioles about 5 cm. in length were floated in water contained in large, cylindrical glass dishes, provided with covers. Moistened conidia were placed on the upper leaf surfaces, some of them being pricked in with a sterile needle, and others being merely laid on the uninjured surface. The covers were allowed to remain on the dishes for 5 days. At the end of 7 days typical spots had appeared, varying in size from tiny flecks to 5 mm. in diameter. The infections occurred not only at the pricked points, but also from the conidia placed on uninjured leaf tissue. Six leaves were used for each isolation in this experiment, and two uninoculated leaves were kept under the same conditions as controls. The controls remained healthy throughout the experiment (about 2 weeks). Reisolations (En 248, En 251) were made from 2 leaves inoculated with *R 214* with which successful infections were obtained. In a similar manner all of the 23 isolations of the fungus were tested, using young, healthy lotus leaves, always keeping several uninoculated leaves under the same conditions as controls. Most of the leaves inoculated from each isolation showed within 5 to 7 days typical reddish brown spots, while in each experiment the controls remained healthy.

In addition to these laboratory inoculations to cut lotus leaves, lotus plants growing in large tubs of soil and water in the greenhouse and out of doors were also inoculated. The method of inoculation was similar except that moist air conditions were obtained by placing bell jars on supports so that the base of the bell jars dipped just below the surface of the water (Plate IV B). The bell jars were left over both the inoculated and control leaves for 3 to 5 days. Fourteen of the different isolations of the fungus were used for these greenhouse inoculation experiments and successful infections were obtained with all (Plate IV A, C). Infections occurred in a majority of cases only where the conidia were introduced, but in one or two instances the infection later spread from the inoculated to the contiguous uninoculated leaves. The controls remained healthy except in these cases. Reisolations were made from all of these artificially infected plants with which the disease was again reproduced. Four of the most virulent of the reisolations were carried successively through healthy plants in order to observe the effect on the virulence of the organism by successive passage through its host. But little difference in virulence could be detected in those reisolations which had been passed four or five times through the host and the original isolations from which they had been subcultured.

The results of the inoculations conducted on lotus plants growing under normal conditions in the greenhouse and out of doors, together with the laboratory inoculations described, leave no doubt as to the pathogenicity of this species of Alternaria to lotus.

Observing the morphological similarity of this species of Alternaria to *Alternaria brassicae nigrescens* (causing leaf-spot of cantaloupe) upon which the authors were also working, several cross-inoculation experiments were carried out with both species of fungus to cantaloupe and lotus. No cross-infections were obtained.

### SOME CULTURAL CHARACTERS

It was found that for growth and sporulation corn-meal agar furnished an excellent medium. Consequently this medium was used for most of the cultural work. On corn-meal agar slants growth is evident after 24 hours as a thin fluffy white surface layer, which at the end of 48 hours becomes tinged with green, and shortly the entire surface is dark green to black, the color also extending down into the medium, where the hyphae have penetrated. At the end of 14 days the thin surface layer is pale smoke gray[1] to smoke gray, and below this the color is olivaceous black to black. The time elapsing before spore-formation varies according to the temperature and perhaps also according to the moisture content of the medium. In some cases spores begin forming at the end of 48 hours and in others not before 3 to 5 days. On potato, growth is very heavy and spores are produced fairly promptly. For the first 5 days the color is lighter than the growth on corn-meal agar, but after ten days it is dark olivaceous to black. A great many flask cultures were made using corn-meal plus litmus milk. In these flasks there is a dense black surface growth, not extending downward. Directly beneath the surface growth there is a layer of brownish pink pseudoparenchyma. The medium is bleached to a cream color throughout, while the control flasks are a dark, livid purple.

On beef agar the mycelium develops slowly, the conidia are produced sparingly and are usually distorted. On this medium the thin surface layer is vinaceous buff, below which the color is brownish.

To determine the relation of temperature to growth corn-meal agar cultures were placed in a large ice thermostat provided with ten compartments ranging in temperature from 2° C. to 18° C. Below 5° C. growth was extremely slow. At the end of 10 days there was no growth at 2° C., but at the end of two weeks in the compartment the colonies

[1]Ridgway, Robert. Color Standard and Color Nomenclature. *43 p. 53 col. pl.* Washington, D. C., 1912.

were 2 to 3 mm. in diameter. At 5° C. growth was slightly more rapid, but no spores developed at either of these low temperatures, even after one month's incubation. At 9° C. growth entirely covered the slant at the end of 10 days, but no spores had at this time developed below 15° C. At the end of one month growth had covered the surface of the slants with production of spores in compartments ranging from 8° C. to 18° C.

The fungus does not lose its virulence readily when grown on a suitable medium at room temperature. Isolations carried in the laboratory for several years and transferred at intervals of 1 to 3 months have always given infections when young cultures were inoculated into healthy lotus plants.

For the purpose of determining the longevity of this fungus cultures were made on corn-meal agar and placed in storage cupboards at room temperature. These cultures were tested for viability at varying intervals up to two years, and even though at this time the agar slants had dried down to hard balls in the bottom of the tubes, nevertheless scrapings from these balls were found to contain conidia of *Alternaria nelumbii* which grew with moderate promptness when transferred to fresh media. Inoculations were later made from these transfers and infections obtained.

## MORPHOLOGY AND TAXONOMY

The mycelium is dark-colored, frequently olivaceous. The conidiophores are slightly lighter in color, 1- to 4-septate, usually erect, rarely in clusters on the host or in media. The conidia are oblong or obclavate to globose, olivaceous, measuring 8 to 18$\mu$ wide by 14 to 65$\mu$ long, average $14 \times 35.2\mu$, with a varying number of oblique, transverse and longitudinal septa (figure 1) where slight constriction occurs, terminating usually in a short, 1- to 2-septate beak, which is hyaline. Round to globose one-celled conidia are frequently found. The conidia have been found in chains of 3 to 8. Their irregular form and size is especially noticeable on media not well adapted to the growth of the

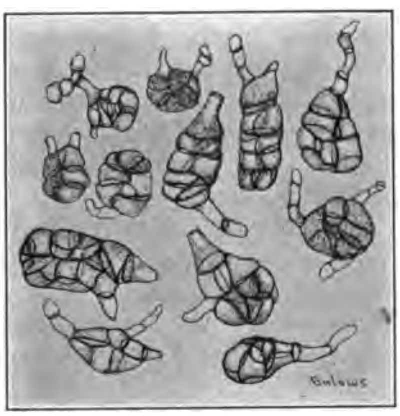


FIG. 1. GERMINATING CONIDIA OF ALTERNARIA NELUMBII

Drawn from a 48-hour corn meal agar culture (Enlows).

fungus. No perfect stage has been discovered for the fungus, but the fact that the conidia are able to germinate after remaining dry in the laboratory for so long a period as 2 years certainly would indicate that the conidia are probably carried over winter on dead leaves and other debris. It grows well saprophytically, so it is also possible that it might growing during the warmer periods of the winter on fallen leaves.

The fungus does not spread far beyond the diseased area on the lotus leaf. Numerous paraffin sections of affected leaves were made, various stains used and careful studies made in an effort to determine the manner of entrance, but in no case were any hyphae found entering stomata. The fungus may either take advantage of wounds which may be present on the leaf surface, or effect entrance through the dissolving effect of toxic products resulting from its growth. The latter seems probable in view of the fact that sections made from inoculated material fixed very soon after the spores had started germinating showed complete disintegration of the epidermal cells immediately underlying the germinating conidia, and disorganization of the palisade cells directly beneath. Older spots show complete disorganization of all the tissue systems in the vicinity of the fungus, but not beyond it. Cells immediately adjacent to those whose cytoplasm has degenerated into more or less homogeneous coagulation products may still contain normally-staining nuclei and chloroplasts.

The fungus as described above differs from any other so far described on Egyptian lotus, and belongs undoubtedly in the genus Alternaria. The name *Alternaria nelumbii* sp. nov. is therefore suggested.

## SUMMARY

The leaf-disease of Egyptian lotus (*Nelumbium speciosum*), here described as caused by *Alternaria nelumbii*, appears as very small, smooth, reddish brown flecks, which later increase in size until they reach a diameter of 5 to 10 mm. The tendency toward the formation of concentric rings is characteristic. The pathogenicity of *Alternaria nelumbii* to lotus has been demonstrated by repeated isolation and successful reinoculation into healthy plants. No perfect stage was discovered, but the longevity of the fungus under laboratory conditions renders it probable that under field conditions it may also be capable of living over long periods of time in the conidial stage.

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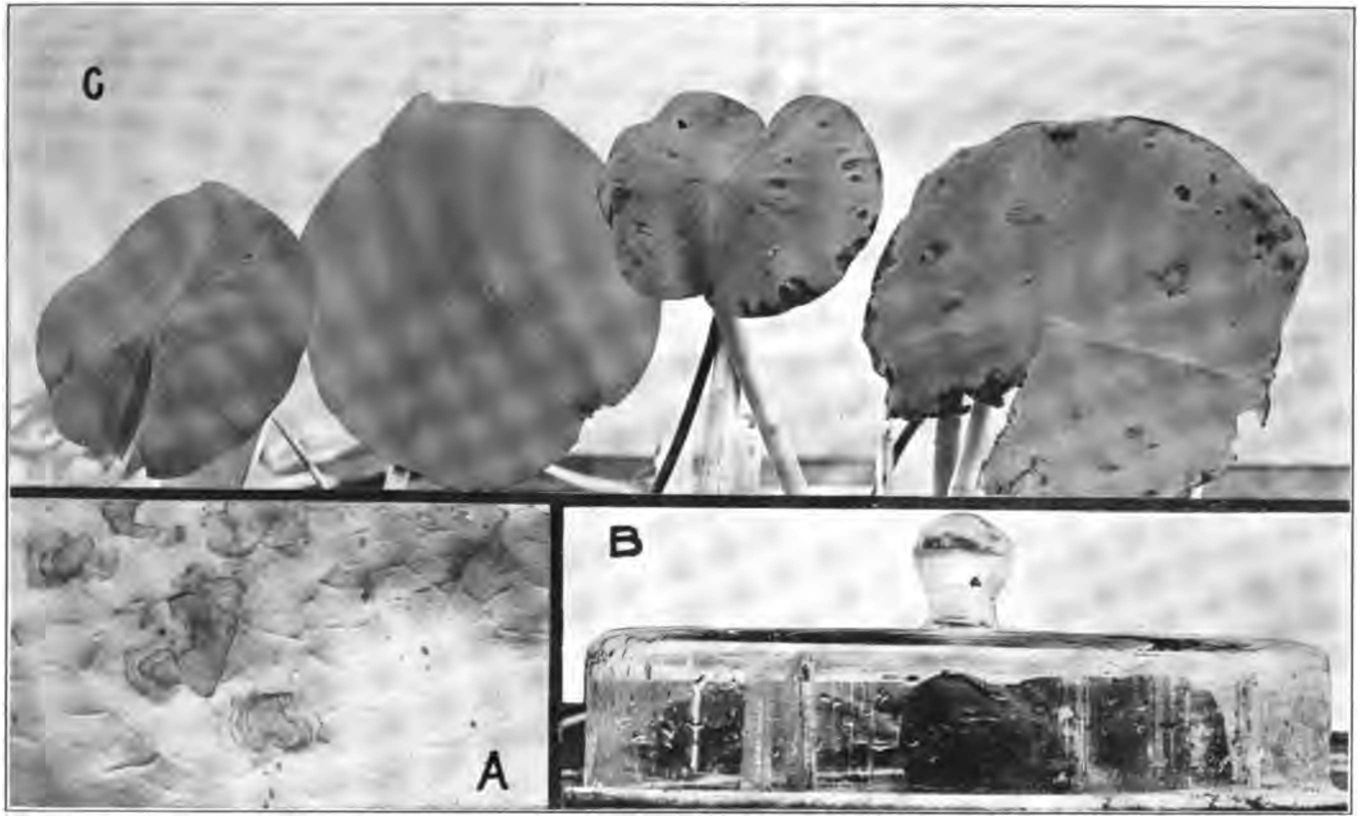
PLATE IV. ALTERNARIA NELUMBII ON LOTUS.

Fig. A. Typical leaf-spots from inoculations of July, 1915. ×2.

Fig. B. Method of forming damp chamber for inoculation of lotus leaves.

Fig. C. Lotus leaves to right inoculated December 21, 1914, with spores of *Alternaria nelumbii* (246) from cornmeal agar culture 6 days old. Two leaves to the left are controls treated in the same way but not inoculated. Photographs by J. F. Brewer.




ALTERNARIA NELUMBII ON LOTUS

# THELEPHORA TERRESTRIS, T. FIMBRIATA, AND T. CARYOPHYLLEA ON FOREST TREE SEEDLINGS

JAMES R. WEIR

WITH PLATE V.

During the field seasons of 1912–1916 a number of specimens of the genus Thelephora were sent to the writer by field and nursery men of the several National Forests in the Northwest with inquiry as to their pathological significance. The specimens were usually accompanied by some such statement as "growing around the base of young trees," "growing around and over seedlings," or "on roots of trees." Two of the species sent have not previously been reported as causing injury to forest tree seedlings.

### THELEPHORA TERRESTRIS (EHRH.) FR.

Robert Hartig (4, 5) reported *Thelephora terrestris* Ehrh. (*T. laciniata* Pers.) as sometimes occurring so abundantly in silver fir, spruce and Weymouth pine plantations that young plants were frequently completely enveloped. This strangling process continued until the tip of the seedling barely projected above the surface of the fungus, resulting in death. In like manner, Hartig reports the smothering of beech seedlings when growing close together. The destruction of spruce seedlings or the branches of older trees which may lie on the ground, by *Thelephora terrestris*, is mentioned by Frank (2, p. 235). The Weymouth pine, firs and red beech were seldom affected. Tubeuf (9, 10) gives brief accounts of the injury to young fir trees and of one-year-old beech seedlings by *Thelephora terrestris*.

An anonymous account (8) of the injurious effects of this fungus on various seedlings, in England, shows that it may extend up the stem for a distance of a foot or more.

Mention of the injury sometimes resulting from the growth of *Thelephora terrestris* around tree seedlings is made by Lindberg (6).

Freeman (3) refers to the fungus in relation to forest tree seedlings, but does not think much damage may result from it in Minnesota. Later references may be found in text-books on plant diseases by Sorauer, Stevens, and others.

It will be seen from the foregoing that *Thelephora terrestris* is the only member of the genus so far reported as injurious to forest tree seedlings. Schrenk (7) has described a root rot of apple trees caused by *Thelephora galactina* Fr. (Nov. Symb. Myc., pp. 136) but this fungus is now classed by Burt in Corticium. Schrenk states that the rot caused

by this organism was transferred from oak roots to young apple trees, killing the latter within a year.

The states and localities in which *Thelephora terrestris* has been observed to injure forest tree seedlings are recorded as follows:

*British Columbia:* encrusting the stems of *Acer macrophyllum*, Salmon Arm: *Pseudotsuga taxifolia* seedling partially enveloped, Agassiz.

*Washington:* on two-year *Pseudotsuga taxifolia* seedling near Olympia; completely enfolding the stem and needles of two-year seedlings of *Pinus monticola*, Metaline Falls, matting the leaves of a clump of two-year seedlings of *Thuja plicata*, Newport.

*Oregon:* growing around the base of young seedlings of *Pinus ponderosa*, Austin.

*Idaho:* growing around the stem and partially enveloping the needles of *Abies grandis*, Priest River; around stems of young *Pseudotsuga taxifolia, Pinus ponderosa* and *Picea engelmani* on nursery area at Priest River Experiment Station.

*Montana:* enveloping the base of an eight-year-old *Larix occidentalis*, not connected with the forest soil, Pattee Canyon, Missoula; (Fig. A) partially enveloping a young seedling of *Pinus contorta*, Anaconda, and on various pine seedlings at the Forest Service Nursery, Haugan.

*Utah:* growing around stem of young *Pinus ponderosa*, locality not given (Forest Service).

*Wyoming:* enveloping seedlings of *Pinus contorta*, Encampment.

*South Dakota:* attached to stem and roots of young *Acer negundo*, Camp Crook.

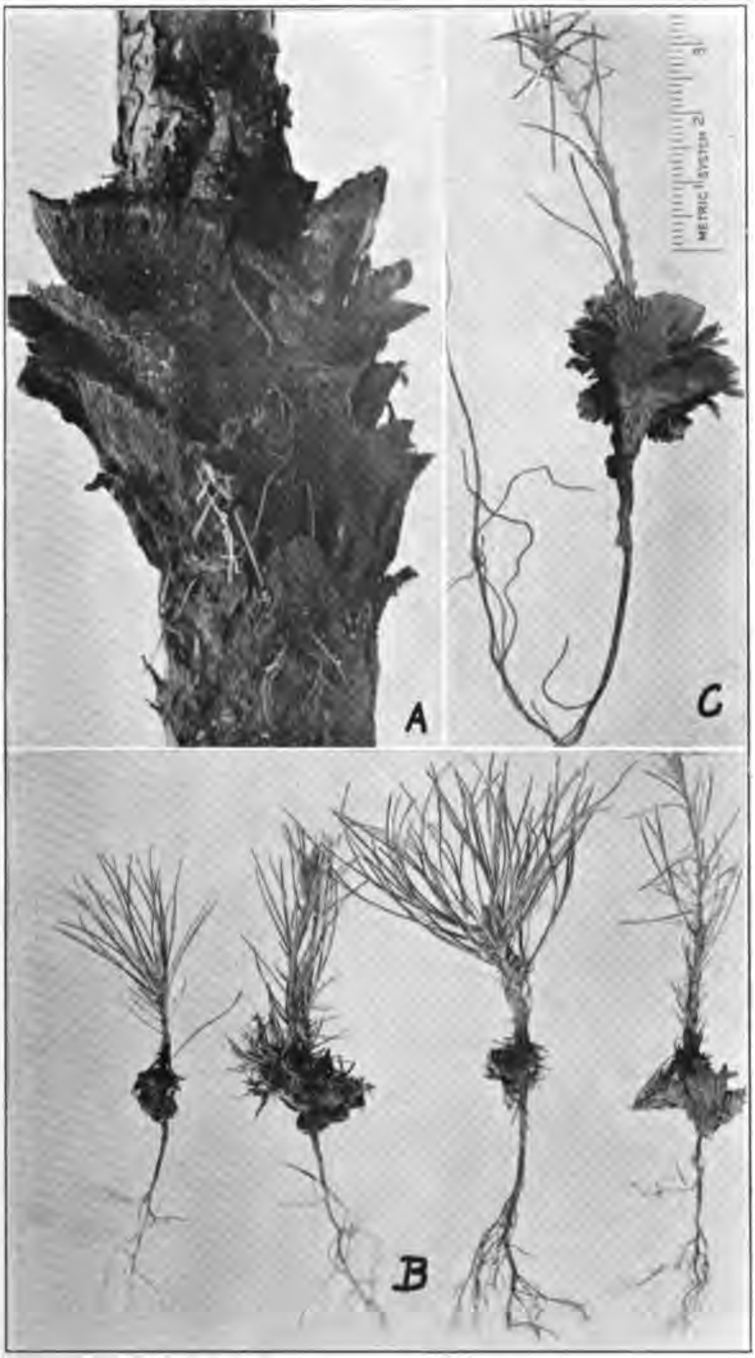
*Minnesota:* enveloping the needles of *Picea mariana*, Ely.

*Michigan:* growing at base and attached to the epidermis of seedlings, *Pinus divaricata*, East Tawas.

*Indiana:* surrounding the stem of two-year-old *Quercus alba*, Weirtown.

Various plants other than forest tree seedlings are overrun and killed by this fungus. An interesting case of the destruction of a seedling of *Ribes prostratum* is shown by a collection made by Dr. A. S. Rhoads, at North Conway, New Hampshire. *Thelephora intybacea* (Pers.) Fries, which resembles *T. terrestris*, is observed to strangle various plants, but has not been recorded on forest tree seedlings.

The fact that *Thelephora terrestris* may envelop a young seedling much more rapidly and more permanently than a number of the fleshy and coriaceous Polypores, is the chief reason why attention is given it, and especially because the fungus frequently appears in the sandy soil of forest tree nurseries. The fungus usually occurs where the seedlings are dense enough to shade the ground. Although the behavior of the fungus is often apparently parasitic, repeated examination of the




THELEPHORA SPP. SMOTHERING CONIFER SEEDLINGS.

young pine seedlings enveloped by it has not shown any living part to be invaded. The mycelium ramifies in the surface soil and merely penetrates the dead outer tissues of any plant encountered. If the plant is completely smothered by the fungus, its mycelium may penetrate into the tissues of the leaves through the stomata and even form a brown layer between the dead bark and wood of the stem. The fungus is very often found hibernating in the thick moist bark at the base of young trees, in which case the mycelia may not be connected with the forest soil (Fig. A). The fungus may draw its nourishment entirely from a moist woody substratum. Burt (1, p. 219, 220) points out the interesting fact that the substratum from which the fungus draws its nourishment exercises an influence on the form and color of the fructification.

When not attached to any woody material the fruiting body is a dark fuscous color and consists of a flattened cluster of small imbricated pileoli, or is composed of a series of super-imposed pileoli. On wood the fructification is of a redder color and reflexed. The habit of growing on both humus and decaying wood is exhibited by a number of the higher fungi which the writer has known to smother seedlings by growing around them. Among them may be mentioned *Polyporus tomentosus*, *Polyporus perennis*, and *Clavaria stricta*.

During damp weather the fungus grows very rapidly and may envelop a small seedling in a comparatively short time. A one-year-old seedling of *Thuja plicata* 5 cm. high, having at its base a young fungus, was completely enveloped in 7 days. A rule set up by the side of the seedling showed that the fungus grew more rapidly during the night, registering in one instance an extension in height of 6 mm. in one night.

Seedlings in nurseries affected with *Thelephora terrestris* should be pulled up and burned. It was found that when this was done at the Savanac Nursery the fungus did not develop in the beds the following year. The use of duff or forest soil in the seed beds promotes the growth of the fungus.

### THELEPHORA FIMBRIATA SCHW.

In the seed beds of the Forest Service nursery at Haugan, Montana, during July, 1914, and again in 1915, *Thelephora fimbriata* appeared in considerable quantity. Two- and three-year-old seedlings of *Pinus ponderosa* were in some cases completely enveloped. The usual type of injury was the complete envelopment of the stem and matting of the lower needles (Fig. B). The late E. C. Rogers reported to the writer that in 1915, at the Haugan Nursery, he found 18 yellow pine seedlings in one bed affected by this fungus.

Seedlings of *Pinus rigida* partially overgrown with *Thelephora fimbriata* were received from H. H. Morgan, of the Pennsylvania Department of Forestry in 1916. The seedlings were from the State Nursery on the Black Forest in Lycoming County. The fungus was reported common.

### THELEPHORA CARYOPHYLLEA (SCHAEFFER) FR.

This fungus was observed growing up around one-year-old seedlings of *Larix occidentalis* (Fig. C) and *Tsuga heterophylla* in seed beds at the Priest River Experiment Station, Idaho, in 1915. Since then it has not reappeared, but is abundant in the surrounding forest, where it is occasionally found enveloping the stems of young lodgepole pine seedlings. This species is one of the most beautiful of the genus and is frequently very abundant in damp coniferous woods.

### SUMMARY

An account of the occurrence of *Thelephora terrestris* on coniferous seedlings in nurseries and on other plants is given. The injury of coniferous seedlings by *Thelephora fimbriata* and *T. caryophyllea* is reported for the first time.

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## BRIEFER ARTICLES

### MOTION PICTURES OF ZOOSPORE PRODUCTION IN PHYTOPHTHORA

G. H. Godfrey and R. B. Harvey

With Plate VI

The liberation of free swimming spores from the zoosporangia of certain of the Phycomycetes has been a process of interest to all pathologists. Numerous investigators have watched and described the events which occur. All have no doubt wished that they might trace more closely the rapidly occurring phenomena step by step, and that they might record them graphically for showing to students or others to whom it is often difficult to give an actual demonstration. It has been the pleasure of the authors to record the sequence of events in a species of Phytophthora by means of the motion picture camera. The film is now available for projection before students, and may be secured by application to the United States Department of Agriculture.

The material used was a species of Phytophthora discovered by Godfrey on rhubarb and as yet unpublished. The process of zoospore formation is remarkable for the rapidity with which it occurs. One sees first as in figure 1 of plate VI,[1] the normal granular protoplasm previous to the appearance of cleavage lines which indicate the approaching activity. In figure 2 practically the same stage is shown. Here a good view of the apical papilla is given under the oil immersion lense. The inner line of the wall of the papilla is still visible, but the tip seems to have softened and swelled up somewhat. In figure 3 this inner line has disappeared and the tip is much swollen. The protoplasm has rounded up into zoospores. This is the last picture taken before the papilla gives way to the increasing pressure within the sporangium. The pictures were taken at the rate of sixteen per second, which is fast enough to show that the tip is being gradually burst outward. Figure 4 was taken as the zoospores were emerging. Some are still within the sporangium while those outside have immediately become active and are caught by the camera swimming about in the field. Figure 5 shows the last zoospore emerging from a sporangium. The movements in passing through the pore are amoeboid, for the opening is much smaller than the zoospore. Several other interesting processes in the development of this fungus have also been recorded by the camera.

[1] Grateful acknowledgement is made of credit due Mr. James F. Brewer of the Office of Plant Pathology for enlargements from the motion picture film used to illustrate this article.

Similar projects with other organisms are under consideration and it is hoped that they may result in the more general application of cinematophotomicrography to teaching and extension work in the biological sciences.

BUREAU OF PLANT INDUSTRY

## A MOSAIC OF SWEET AND RED CLOVERS

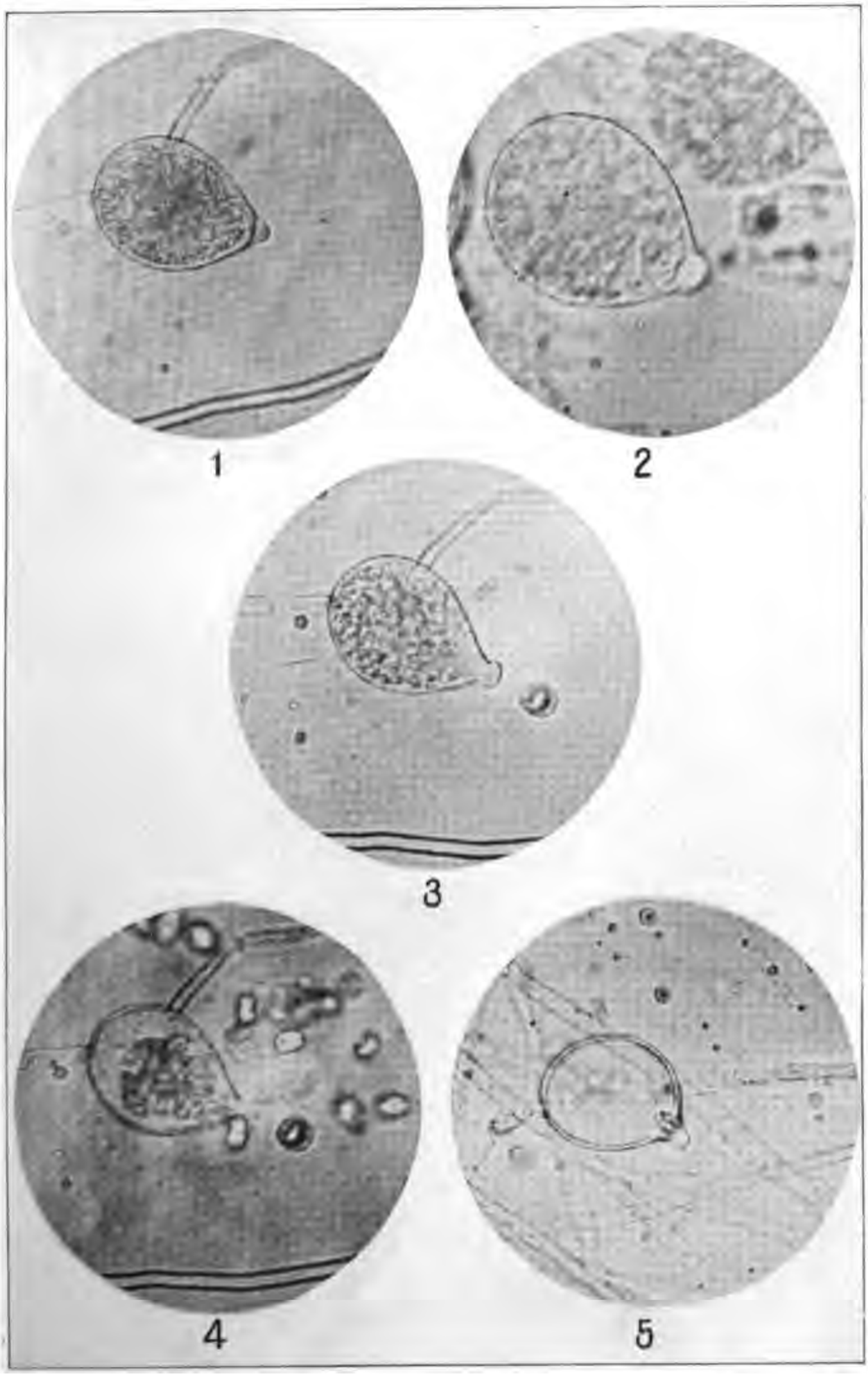
JOHN A. ELLIOTT

WITH ONE FIGURE IN THE TEXT

In the November, 1920, issue of Phytopathology, H. R. McLarty (2) published a short note on a mosaic of sweet clover (*Melilotus alba*) which he has had under observation. Rosen (4) had previously mentioned this disease as being under observation at the Arkansas Experiment Station, in his bulletin on The Mosaic Disease of Sweet Potatoes published in April, 1920. Clinton (1) also mentions a chlorosis of common species of clover in his publication on Chlorosis of Plants published in 1915.

The mosaic of sweet clover first came to my attention in the summer of 1917 when it appeared on about fifty per cent of the sweet clover plants on the University of Arkansas campus. As the plants were growing wild and were rather widely scattered, inoculation experiments were attempted on several apparently healthy plants, using crushed leaves from diseased plants as the inoculum. The results in all cases were positive. Several mosaic plants were marked for observation on the following season. All of the marked plants which grew the following year showed the characteristic symptoms of the disease early in the season.

In September of 1919 it was noted that not only the sweet clover but the red clover (*Trifolium pratense*) showed very marked symptoms of the disease. At this time of the year fully seventy-five per cent of the red clover plants on the campus were very severely attacked, the symptoms being much more pronounced on the red clover than on the sweet clover. Several healthy red clover and sweet clover plants were placed in pots in the greenhouse and after a suitable period of observation for signs of the disease due to natural infection, cross inoculations with infectious material from diseased plants were attempted. All attempted inoculations were successful and there appeared to be no difference in the disease from the different sources. Inoculations were also attempted on white clover (*Trifolium repens*) and alfalfa (*Medicago sativa*), none of which were successful. White clover and alfalfa were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growing intermixed with the infected sweet clover and red clover everywhere on the campus, but no appearance of the mosaic symptoms on either of these plants has been noted in the four summers' observations, and repeated attempted inoculations have failed.

To have a more satisfactory check on the work that had been done with transplanted plants, seed of several legumes, from commercial seed houses, was secured and planted in pots in the greenhouse. The legumes chosen[1] were horse bean (*Vicia faba*), alfalfa, white clover, sweet clover, spotted burr clover (*Medicago arabica*), and red clover. When these plants had attained sufficient size for convenient handling and were seen to be free from any symptoms of mosaic, two plants of each species were inoculated from each of the sources of infection, *i. e.*, diseased sweet clover and red clover plants. Inoculations from both sources appeared equally virulent on the different plants proving susceptible. The disease usually appeared simultaneously on all of the plants inoculated in from ten to fifteen days. The plants which proved susceptible were sweet clover, red clover, burr clover and horse bean. No infections occurred on white clover or alfalfa even after repeated

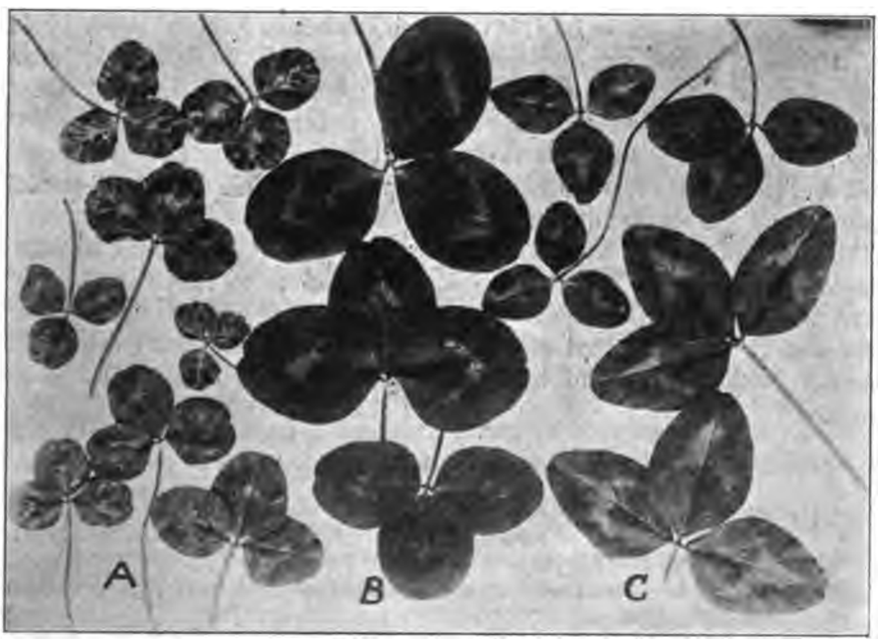


**FIG. 1.** *A*. Mosaic on red clover leaves. Natural infection. *B*. Healthy red clover leaves. *C*. Mosaic on red clover leaves about fifteen days after artificial inoculation.

[1] Common beans and cow peas were also planted but were destroyed by mice.

attempts at artificial infection and after all of the susceptible plants around them had become diseased either through artificial or natural inoculation. The disease appeared to be extremely virulent on the spotted burr clover.

A large red clover plant which had been used as one of the sources of the inoculum was allowed to grow in the greenhouse throughout the winter. In the spring it was noted that all signs of mosaic had disappeared from this plant, although the disease had remained throughout the winter on the sweet clover, horse bean, and burr clover. Crushed leaves from this plant failed to inoculate healthy red clover and sweet clover plants, but it was again inoculated from a burr clover plant. Careful observations were made in the field when the red clover and sweet clover began to grow in the spring of 1920. Mosaic appeared on very young shoots of sweet clover when it could not be found on red clover. The disease began to appear on the red clover somewhat later. It was thought possible that the disease was carried over the winter only on the sweet clover, but in an orchard in which red clover was abundant and in which no sweet clover was observed, the disease appeared approximately as early as on red clover in the mixed growth of red and sweet clover on the University campus.

Mosaic of beans and cow peas is very common in Arkansas, both cow peas and beans showing an extreme type of the disease in many instances. The inoculation experiments conducted would seem to point to the probability that the mosaic diseases on beans, cow peas, red clover, and sweet clover are identical, since the mosaic from both sweet clover and red clover infected four different genera of the leguminosae, Trifolium, Melilotus, Vicia and Medicago, and was apparently equally infectious on each. The reason for the failures to inoculate alfalfa and white clover are not evident, possibly further efforts might prove successful. Reddick and Stewart (3) had the same experience with certain varieties of beans in their inoculation experiments with bean mosaic.

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# A MODIFICATION OF THE CONCENTRATED FORMALDEHYDE METHOD OF SEED TREATMENT

CHAS. W. HUNGERFORD

The concentrated formaldehyde method of seed treatment as proposed by Haskell[1] for the control of the smuts of oats, has many advantages over the formaldehyde dip or sprinkle methods and has recently become very popular in various parts of the United States. It seems to have proven quite uniformly successful wherever thoroughly tested in controlling the smuts of oats. This method calls for the application of a solution containing one part of 40 per cent formaldehyde and one part of water to the grain by means of a hand sprayer. The solution is to be applied at the rate of one quart to fifty bushels of oats. It has been considered that one stroke of the piston of the sprayer would deliver enough of the solution for each shovelful of grain.

It has been the experience of the writer that it is very difficult to apply uniformly so small an amount of solution to such a large amount of grain. This is especially true as the common quart sprayers vary greatly in the amount of solution which they will deliver at a single stroke of the piston. Another very serious objection to the method as proposed by Haskell has been that the fumes of such a strong solution of formaldehyde are very irritating to the mucus membrane of the nose and throat. Even when the grain is treated in the open air there has been more or less inconvenience experienced from this source.

In order to overcome these difficulties the writer has for the last three years thoroughly tested a modification of this method which has proven very satisfactory. Instead of equal parts of formaldehyde and water, ten parts of water to one of formaldehyde have been used. This makes a larger amount of the solution and it is therefore much easier to apply evenly to a given amount of seed. This modification moreover still retains the advantages of the "dry" method in that the grain is not wet sufficiently to necessitate drying. The fumes of the formaldehyde are not noticeable when this weaker solution is used. It is possible indeed to apply the solution in a closed room and not experience any inconvenience.

As stated above this modified method has been thoroughly tested for three years. Perfect control has been secured in every instance both in experimental plots and when the method has been used by farmers on a field basis. In 1918, at Corvallis, Oregon, badly smutted oats were treated with formaldehyde according to the standard dip method, the concentrated formaldehyde method, and the modified method as

[1] Haskell, R. J. The spray method of applying concentrated formaldehyde solution in the control of oat smut. Phytopath. 7: 381–383. 1917.

outlined above. All three methods gave perfect control altho the checks were heavily smutted. In 1919 and again in 1920 at Moscow, Idaho, all three methods were again tested. In 1919 three lots of smutted oats were used with each treatment. These gave 12, 3 and 2 per cent smut respectively when untreated seed was planted. Perfect control was secured with each treatment except that lot number 1, which gave 12 per cent smut when untreated, gave 1 per cent when treated by the concentrated formaldehyde method.

In 1920 badly smutted Swedish Select oats when untreated gave 30 per cent smut while the same oats treated with the modified method as outlined above gave perfect control.

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## A NOTE ON THE CORROSIVE SUBLIMATE TREATMENT FOR THE CONTROL OF RHIZOCTONIA

H. W. THURSTON, JR.

Early in the spring of 1918, in connection with certain investigations on potato seed treatments being conducted at the University of Nebraska, the writer had occasion to make numerous plate cultures of Rhizoctonia from tubers treated with $HgCl_2$ solution at varying strengths and for varying lengths of time. In view of the recent studies of Melhus and Gilman[1] it has seemed advisable to present this data in brief form.

The general method of procedure was as follows: tubers bearing numerous sclerotia were soaked in corrosive sublimate, then carefully rinsed in sterile water. The sclerotia were picked off with a sterile scalpel and transferred to plates of potato agar. The plates were kept three days at a temperature of 27° to 30° C. after which the number of sclerotia that were growing were counted. The results are presented in the following table. It is noticeable that much better control was indicated in the shorter treatments with 1–1000 $HgCl_2$ and also with 1–2000 $HgCl_2$ than that reported by Melhus and Gilman. At dilutions greater than 1–2000 it was noticed that many sclerotia started to grow from the center, though the exterior was apparently killed by the fungicide. This was also noticed by Melhus and Gilman and described by them as the antiseptic rather than disinfectant effect of the fungicide. Unfortunately lack of available land did not permit the checking of these results under field conditions.

[1] Melhus, I. E. and Gilman, J. C. Measuring certain variable factors in potato seed treatment experiments. Phytopath. 11: 6–17. 1921.

TABLE 1

*Action of $HgCl_2$ on Sclerotia of Rhizoctonia*

| DILUTION | TIME | NO. SCLEROTIA PLANTED | PER CENT SCLEROTIA GREW |
|---|---|---|---|
| Checks (water) | 60 min. | 190 | 79 |
| 1-1000 | 5 " | 60 | 0 |
| 1-1000 | 30 " | 130 | 0 |
| 1-1000 | 120 " | 100 | 0 |
| 1-1500 | 5 " | 40 | 50 |
| 1-1500 | 30 " | 40 | 0 |
| 1-1500 | 120 " | 50 | 0 |
| 1-2000 | 5 " | 60 | 66 |
| 1-2000 | 30 " | 140 | 7.1 |
| 1-2000 | 120 " | 80 | 0 |
| 1-2500 | 5 " | 50 | 20 |
| 1-2500 | 30 " | 60 | 5 |
| 1-2500 | 120 " | 50 | 0 |
| 1-3000 | 5 " | 50 | 80 |
| 1-3000 | 30 " | 140 | 16 |
| 1-3000 | 120 " | 90 | 22 |
| 1-4000 | 30 " | 90 | 10 |
| 1-4000 | 120 " | 30 | 0 |
| 1-5000 | 30 " | 80 | 12 |
| 1-5000 | 120 " | 40 | 0 |
| 1-6000 | 30 " | 120 | 18 |
| 1-6000 | 120 " | 90 | 11 |
| 1-7000 | 30 " | 70 | 14 |
| 1-7000 | 120 " | 40 | 2 |
| 1-8000 | 30 " | 90 | 11 |
| 1-8000 | 120 " | 60 | 6 |
| 1-9000 | 30 " | 110 | 18 |
| 1-9000 | 120 " | 40 | 25 |
| 1-10000 | 30 " | 100 | 60 |
| 1-10000 | 120 " | 40 | 30 |

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## FIELD CULTURES OF WOOD-ROTTING FUNGI ON AGARS

BESSIE E. ETTER

This article gives the apparatus needed for field inoculations on agar, method of packing the culture media for shipment, methods of inoculation, and the results obtained from the inoculations.

Many laboratories and schools have built culture rooms or inoculation chambers on the theory that such rooms were necessary if pure cultures

on artificial media were to be obtained; and text books on plant diseases usually recommend some form of culture room for such work.[1] In an article by Long and Harsch,[2] attention was called to the purity of both initial and sub-cultures, when made in an ordinary room without the use of any special inoculation chamber. In this case the purity of the cultures was attributed to the very dry climate of Albuquerque.

The data given in this article show that with proper care in making the inoculations, a high percentage of pure cultures can be obtained without the use of any culture room in moist or even wet climates, as well as in a dry climate.

The inoculations here reported were made in the field, without the use of inoculating chambers of any kind, in the following states: Kentucky, Mississippi, Louisiana, Florida, New Mexico, Arizona, Tennessee, and California, and in towns ranging in size from mere villages of one thousand population to cities of over three hundred thousand.

In New Orleans, the cultures were made during very foggy weather, and yet in spite of the moisture and the large amount of soot, and other foreign bodies in the air, the cultures were comparatively free from external contamination. Similar results were obtained at all the various places where the inoculations were made.

## APPARATUS NEEDED FOR FIELD INOCULATIONS

The apparatus needed for field inoculations of wood-rotting fungi is neither complicated nor large in amount, as is shown by the following list: alcohol lamp, long-handled scissors, inoculating needles, scalpels, mallet, hatchet, saw, labels, alcohol, and a bottle containing alcohol for holding the scalpel and scissors when the actual inoculating is being done.

## METHOD OF PACKING THE CULTURE MEDIA

Proper packing of the media is one of the most important features for the success of field inoculations since the culture media must be in such shape that it can be transported from place to place without danger of contamination or serious breakage. Both of these difficulties were avoided by using strong wooden boxes with hinged and padlocked tops, in which were packed heavy pasteboard boxes holding 72 test tubes each.

Necessary ventilation was obtained by boring 5 holes, one-half inch in diameter, in two sides of each wooden box. The paste-board boxes

[1] Smith, Erwin F. Bacteria in Relation to Plant Diseases, *485 p.* 1905, and Duggar, B. M. Fungous Diseases of Plants, *508 p.* 1909.

[2] Long, W. H. and Harsch, R. M., Pure cultures of wood-rotting fungi on artificial media, Jour. Agric. Res. **12**: 33–82. 1918.

held 6 layers of 12 test tubes each. These layers were separated from each other by corrugated paste-board, while the test tubes were separated by strips of the same material. The paste-board boxes were lined with currugated paste-board throughout and were an inch and a half wider than the length of the test tubes, thereby giving ample space for ventilation in each box. If the paste-board and wooden boxes are air tight, moisture will collect on the plugs in the test tubes and contamination, especially with molds, may result. The essential part in packing each paste-board box to prevent breakage in transit is to have the box so full that when its top is put on the tubes will be firmly held in place. The paste-board boxes should be securely tied with strong twine and fitted very tightly into the wooden boxes. It was found very convenient to pack an equal number of corn meal and malt agar tubes in each paste-board box, since 5 corn meal and 5 malt were used for each set of inoculations. Forty-two hundred test tubes, packed as above described were used in the field work discussed in this paper, and not a single test tube was contaminated in transit and only two were broken, in spite of the fact that some of these boxes of tubes were shipped from headquarters at Albuquerque, as far east as Florida, and as far west as California.

### MEDIA USED

Corn meal agar and malt agar gave the best results for initial inoculations. Hard agars, say at least 3 per cent, adjusted to plus 1 Fuller's scale, in test tubes 20 by 150 millimeters, filled about two-thirds full and slanted were found best suited for field work. If the agar is not hard, the jarring incident to the shipping from place to place will cause it to break up and it then becomes unsuited for cultures.

### METHODS OF INOCULATION

Any room closed sufficiently to prevent pronounced air currents proved satisfactory for inoculation purposes. All the inoculations were made on tables which had been freed from dust by a damp cloth, then covered with a freshly laundered towel. The scalpel and scissors were kept, during the period of inoculation, (when not in actual use) in a bottle of alcohol, and flamed red hot over an alcohol lamp before each inoculation. The inocula used consisted of pieces of diseased wood or of sporophores, which were carefully selected so as to be as free from molds and bacteria as possible. The diseased wood or sporophores were then split and the inocula taken from near the center of the freshly exposed surface. In making cultures from perennial sporophores the writer used with great success sections of the tubes of such species as

Fomes and Ganoderma for inocula. Pieces 2 by 2 by 5 millimeters were found more satisfactory than either larger or smaller pieces. The inocula should be inserted in the agar so as to leave at least one third of the piece exposed.

## RESULTS OF INOCULATIONS

In the Mississippi Valley and Atlantic Coast States 240 sets of cultures were made, including 16 genera of fungi as follows: Armillaria, Corticium, Daedalea, Fomitiporia, Fomes, Ganoderma, Hydnum, Lentinus, Lenzites, Marasmius, Pholiota, Pleurotus, Polystictus, Polyporus, Poria, and Stereum also two unknown heart-rots. Of the 2400 tubes inoculated 590 showed contamination. The contamination in 577 of these tubes, unquestionably was already in the inocula. This leaves 13 tubes out of the 2400 which were contaminated by spores from the air.

Eighteen hundred test tubes were inoculated on the western trip. 12 genera were represented in these inoculations as follows: Cenangium, Fomes, Ganoderma, Irpex, Lentinus, Lenzites, Polyporus, Polystictus, Poria, Pleurotus, Stereum, and Trametes. 121 (less than 7 per cent) of these 1800 tubes showed contamination. Of this number only 4 showed contamination from the air.

The results obtained from both the eastern and western cultures show contamination from external sources as follows: 13 tubes out of 2400 (eastern) and 4 out of 1800 (western), or 17 out of 4200 test tubes inoculated, making an average of only 0.4 per cent contamination. This shows that cultures of wood-rotting fungi on artificial media can be satisfactorily performed in the field under varied climatic conditions if the precautions outlined in this article are followed.

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ALBUQUERQUE, N. M.

## PHYTOPATHOLOGICAL NOTES

*Symposium on dusting at the Chicago meeting.* The American Phytopathological Society met in joint session with the American Association of Economic Entomologists at Chicago on December 21, 1920, for a program covering the subject, "Dusting as a Means of Controlling Injurious Insects and Plant Diseases." There were three papers on insect control and two papers on plant disease control. Prof. P. J. Parrott of Geneva, N. Y., reported the results of experiments on control of sucking insects by dust mixture, especially apple aphids, red bugs, currant aphids, and pear Psylla. Dr. T. J. Headlee of New Brunswick, N. J., presented data in regard to dusting as a means of controlling sucking and biting insects, with special reference to the plum curculio and the codling moth. Dr. A. L. Quaintance of Washington, D. C., reviewed some of the work of the U. S. Department of Agriculture on dusting vs. spraying of apples. Dr. H. A. Edson of Washington, D. C. gave a summary of the disease control work as related to truck crops. Dr. N. J. Giddings presented a general review of the investigations regarding orchard disease control.

The five papers, with the discussion which followed their presentation, will appear in the April number of the Journal of Economic Entomology where they will be accessible to pathologists interested in the subject of dusting.—N. J. GIDDINGS.

*Recognition of scientific accomplishments.* On January 6, 1921, at a "Utility Corn Show" held at Galesburg, Illinois, Mr. J. R. Holbert, Agrononomist, Office of Cereal Investigations, U. S. Department of Agriculture, received highly merited recognition at the hands of Illinois farm advisers and corn breeders. Mr. Eugene D. Funk, chairman, presented Mr. Holbert with a beautiful silver loving cup enscribed as follows: "Awarded to J. R. Holbert in recognition of unselfish devotion to study of corn diseases," it being recognized that Mr. Holbert has done much in developing, in Illinois, the smoother types of corn which are proving more resistant to the root and stalk rots. These smoother types have been found to produce higher and more satisfactory yields than the rougher types encouraged by the old score card. Accordingly, a new and specially prepared score card was used in the Galesburg Utility Corn Show.—A. G. JOHNSON.

*Phytopathological research in Russia.* For the last four or five years we have received not a single phytopathological paper from Russia. We have had no information even as to whether work on plant diseases was being carried on, and if so in what institutions and under what direction. We now learn at least that phytopathological research has been preserved and apparently there is good prospect that it may be given additional opportunity for growth and development. The Slavic Division of the Library of Congress, Washington, D. C., is in receipt of a copy of an official journal of the Commissariat of Agriculture of the R. S. F. S. R.* (Vestnik Narodnogo Komissariata Zemledelia, No. 1, January, 1919). It consists of 90 pages and contains articles relative to the agricultural policies of the government and semi-popular articles on various topics. Among these there is one entitled "The Status of the Experimental Division in the System of Organization of the Commissariat of Agriculture" (pp. 55–59). From this it appears that the organization and conduct of the major part of the experimental work in Russia is to be supervised and facilitated by an office of the Commissariat, known as the Experimental Division. Enumerating various categories of investigational activities which are placed in the jurisdiction of the latter, the article refers to plant pathology in the following paragraph: "8. Study of enemies of agricultural plants, of orchard, garden, and vineyard and working out means of combatting them (entomological and phytopathological investigations and measures of combatting animal and plant parasites)." The number also contains announcements of several other agricultural journals and of a series of pamphets, circulars, and colored posters. It is to be hoped that the Library of Congress may be successful in procuring additional Russian publications from which we may learn more about phytopathological research in Russia.—M. SHAPOVALOV.

* Russian Socialist Federal Soviet Republic.

# THE AUK

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# PHYTOPATHOLOGY

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## AN ATTACK OF POPLAR CANKER FOLLOWING FIRE INJURY


ALFRED H. W. POVAH


WITH THREE FIGURES IN THE TEXT

### INTRODUCTION

Three years ago Long (3) described a poplar canker caused by *Cytospora chrysosperma* (Pers.) Fr. as occurring commonly in the Southwest. He pointed out that this disease is not "an active parasite on the well-cared for, more resistant species of poplar," but attacks trees only when their resistance is lowered by such adverse conditions as (a) lack of water, (b) unfavorable environment, and (c) severe pruning. He found that cuttings in propagation beds are subject to the disease. Long lists ten species of poplar and three species of willow as hosts.

Recently Hubert (2) has given data on hosts and range of this pathogen in the Northwest. He notes that this disease often follows fire injury. As new hosts are given: three species of maple, *Prunus demissa*, *Sambucus glauca*, *Populus trichocarpa*, *Salix lasiandra*, and *Sorbus scopulina*.

Concerning the distribution of the fungus Long (3) says "*Cytospora chrysosperma* is rather widely distributed in certain sections of the United States, especially in the Southwestern States. It ranges from Texas and Kansas northward to Montana and westward to California. It has been found in nine states—Arizona, Colorado, Kansas, Montana, Nevada, New Mexico, North Dakota, South Dakota, and Texas; and also in Mexico. The fungus is widely distributed in Europe." Hubert (2) adds Idaho, Washington and Wyoming to the list, making a total of twelve states. So far as the writer is aware the disease caused by this fungus is here reported for the first time from east of the Mississippi.

### FIELD DATA

The writer's attention was first called to this disease the early part of

last June when he noticed, beside a railroad track in the vicinity of Syracuse, N. Y., a small tree of *Populus grandidentata* Michx. (Tree No. 1, table 1), 1¾inches in diameter which had died when the new shoots were 1½ inches long (Fig. 1). Upon examination this tree was found to be heavily infected with *Cytospora chrysosperma*,[1] one canker extending from the ground 3½ feet up the trunk. Infections covering approximately two-thirds of the surface were found on two branches each 1 inch in diameter, located about 1 foot above the ground. These two branches were killed just as the buds opened (Fig. 1).

A glance showed that a light ground fire had run through the woods, probably set by a spark from a passing locomotive. Inquiry of one of the railroad men placed the approximate time of the fire as the middle of April. Apparently the disease was limited to the burned area as trees close to infected ones were not diseased if they were not in the path of the fire. Moreover, an examination of the poplars in the surrounding territory failed to reveal a single case of infection. It should be pointed out that although the pathogen is a weak parasite it can kill when the host is in a weakened condition. The mortality, as shown in table 1, is believed to be due to the disease as no case was found in the area in which fire injury was sufficient to cause death. In a few places the shrubs had been killed by the fire but, from the general appearance of the area, it was concluded that the effect of the fire was relatively small as far as the trees were concerned.

FIG. 1. POPLAR KILLED BY CYTOSPORA CHRYSOSPERMA.

Tree of Populus grandidentata (No. 1, table 1) killed when the new shoots were 1½ inches long. The two lower branches were killed as the buds opened.

A survey of the area showed that both *P. grandidentata* and *P. tremuloides* Michx. were infected. Table 1 shows the result of a survey on July 23. From this table we note that of the 73 poplars in the area, 50 were infected and 27 killed. Expressed in percentage this would be 68.4 per cent infected and 36.9 per cent killed. Of the 43 trees of *P. tremuloides* 31 trees, or 72 per cent were infected and 21 trees, or 48.9 per cent killed. In the case of *P. grandidentata* we find that 19 of the

[1] Material was submitted to W. H. Long who confirmed the author's identification.

TABLE 1.

*Field data on Populus tremuloides and Populus grandidentata*

| TREE NUMBER | SPECIES* | DIAMETER BREAST HIGH IN INCHES | STATE (U = UNINFECTED I = INFECTED) | SIZE OF CANKER | CONDITION OF TREE JULY 23 |
|---|---|---|---|---|---|
| 1 | G | 1.75 | I | Girdled for 1½ ft. | Killed when new shoots 1½ in. |
| 2 | G | 1.50 | I | Girdled for 8 ft. | Killed as buds opened |
| 3 | G | 2.00 | I | 1 ft. × 3 in. | Still living |
| 4 | G | 1.25 | I | 4 ft. × 3 in. | Still living |
| 5 | G | 0.50 | I | Girdled for 2 ft. | Killed as buds opened |
| 6 | T | 1.00 | I | Tree covered | Killed before buds opened |
| 7 | T | 1.00 | I | Tree covered | Killed before buds opened |
| 8 | G | 4.75 | U | | Healthy |
| 9 | G | 5.75 | U | | Healthy |
| 10 | G | 4.75 | U | | Half dead |
| 11 | G | 3.50 | I | 1 ft. 4 in. × 3 in. | Still living |
| 12(1) | G | 3.50 | U | | Living |
| 13 | G | 2.50 | U | | Living |
| 14 | G | 4.75 | U | | Living |
| 15 | G | 4.75 | I | 4 ft. × 4 in. | One third dead |
| 16 | G | 4.25 | I | 4⅓ ft. × 6 in. | Living |
| 17 | G | 6.00 | U | | Living |
| 18 | G | 7.00 | I | 5⅓ ft. × 5 in. | Living |
| 19 | G | 4.75 | I | 6 ft. × 6 in. | Living |
| 20 | G | 3.25 | U | | Living |
| 21 | G | 5.25 | I | 5 ft. × 6 in. | Living |
| 22(2) | G | 4.25 | I | 4½ ft. × 5 in. | Partly dead |
| 23 | G | 6.75 | I | 3½ ft. × 10 in. | Living |
| 24 | G | 4.75 | I | 4½ ft. × 7 in. | Living |
| 25 | G | 3.75 | I | 4 ft. × 6 in. | Living |
| 26 | G | 2.50 | U | | Dead for some time |
| 27 | G | 4.75 | U | | Living |

TABLE 1. Continued

*Field data on Populus tremuloides and Populus grandidentata*

| TREE NUMBER | SPECIES* | DIAMETER BREAST HIGH IN INCHES | STATE (U = UNINFECTED I = INFECTED) | SIZE OF CANKER | CONDITION OF TREE JULY 23 |
|---|---|---|---|---|---|
| 28 | T | 2.25 | I | 10 ft. × 4 in. | Living |
| 29 | T | 2.00 | I | Girdled for 8 ft. | Killed |
| 30(3) | T | 2.00 | I | 10 ft. × 4 in. | Still living |
| 31 | T | 1.75 | I | 8 ft. × 3 in. | Still living |
| 32 | G | 2.25 | I | 5½ ft. × 3 in. | Killed as buds opened |
| 33 | T | 1.75 | I | Tree covered | Killed as buds opened |
| 34 | T | 3.25 | I | 3 ft. × 3½ in. | Still living |
| 35(4) | T | 1.75 | U | | Sickly with scale |
| 36 | T | 2.75 | U | | Sickly with scale |
| 37(5) | G | 2.50 | I | 6 ft. × 4 in. | Almost dead |
| 38 | T | 1.125 | I | 2 ft. × 2 in. | Living |
| 39 | G | 2.25 | U | | Living |
| 40 | T | 2.00 | U | | Living |
| 41 | T | 1.50 | U | | Living |
| 42 | T | 2.25 | I | Girdled | Killed before buds opened |
| 43 | T | 4.75 | U | | Living |
| 44 | T | 4.50 | U | | Living |
| 45 | T | 2.50 | U | | Living |
| 46 | T | 3.50 | U | | Dead |
| 47 | T | 5.00 | U | | Living |
| 48 | T | 2.50 | I | 4 ft. 5 in. × 5½ in. | Half dead |
| 49 | T | 3.50 | I | 3 ft. × 4 in. | Half dead |
| 50 | T | 5.00 | I | Almost girdled for 5 ft. | Almost dead |
| 51 | T | 1.00 | I | Tree covered | Killed as buds opened |
| 52 | T | 1.00 | I | Tree covered | Killed as buds opened |
| 53 | T | 1.00 | I | Tree covered | Killed as buds opened |

TABLE 1. Continued

*Field data on Populus tremuloides and Populus grandidentata*

| TREE NUMBER | SPECIES* | DIAMETER BREAST HIGH IN INCHES | STATE (U = UNINFECTED I = INFECTED) | SIZE OF CANKER | CONDITION OF TREE JULY 23 |
|---|---|---|---|---|---|
| 54 | T | 1.50 | 1 | Tree covered | Killed when shoots were 2 in. |
| 55 | T | 1.50 | 1 | Tree covered | Killed when shoots were 1½ in. |
| 56 | T | 1.50 | 1 | Girdled for 3 ft. | Killed when shoots were 2 in. |
| 57 | T | 1.00 | 1 | Girdled for 3 ft. | Killed when shoots were 1½ in. |
| 58 | T | 1.00 | 1 | Girdled for 3 ft. | Killed as catkins opened |
| 59 | T | 1.50 | 1 | Girdled for 2 ft. | Killed when shoots were 1½ in. |
| 60 | T | 1.75 | 1 | 2 ft. × 3 in. | Sickly, leaves undersized |
| 61 | T | 2.50 | 1 | Girdled for 3 ft. | Killed when shoots were 2 in. |
| 62 | T | 1.75 | 1 | Tree covered | Killed when shoots were 1½ in. |
| 63 | T | 0.50 | 1 | Tree covered | Killed before buds opened |
| 64 | T | 1.00 | 1 | Tree covered | Killed as catkins opened |
| 65 | T | 1.00 | 1 | Tree covered | Killed when shoots were 1½ in. |
| 66 | T | 0.50 | 1 | Tree covered | Killed as catkins opened |
| 67 | T | 1.25 | 1 | Tree covered | Killed when shoots were 1 in. |
| 68 | T | 0.75 | 1 | 2 ft. × 1 in. | Fair |
| 69 | T | 0.75 | U | | Fair |
| 70 | T | 2.50 | U | | Poor, covered with scale |
| 71 | T | 1.50 | U | | Sickly with scale |
| 72 | G | 1.00 | 1 | Girdled | Killed before buds opened |
| 73 | G | 3.50 | U | | Living |

* G=Populus grandidentata, T=P. tremuloides.

(1) Oct. 21, 1920. Two small cankers each 2 in. × ¾ in. Still living.
(2) " Top dead and blown off.
(3) " Dead.
(4) " Dead.
(5) " Dead.

30 trees, or 63.3 per cent were infected and 6 trees, or 20 per cent were killed. It is believed that the higher mortality among the quaking aspens is due to the larger number of younger trees. We note, for example, that 67 per cent of the trees of this species, as compared with 20 per cent of the large-toothed aspens, do not exceed 2 inches in diameter.

### DESCRIPTION OF CANKER

On the trunks of small trees and on small branches the canker is very conspicuous because of its color, recalling somewhat the chestnut tree blight. Here the canker appears as a slightly sunken area which is cinnamon to orange cinnamon (5) in color. Thus it is sharply delimited

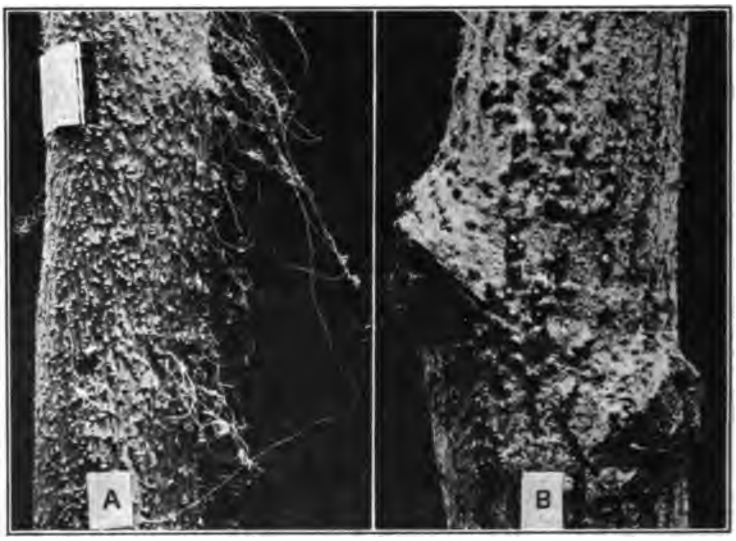


FIG. 2. TWO TYPES OF PYCNIAL EXUDATE
*A*. Artificial infection on *Populus grandidentata* in laboratory.
*B*. Natural infection on *Populus grandidentata* from diseased area.

from the grayish olive to deep grayish olive (5) color of the healthy bark. Usually the pustules are surrounded by a narrow (up to 1 mm.) band of the greenish color of the healthy bark. Both types of pycnial exudate, as mentioned by Hubert (2), were found. In the laboratory during wet weather the pycnial hairs become very long. The same result is obtained when material is kept under a bell jar. This is shown in figure 2 A where some of the spore tendrils measure 7 cm. Figure 2 B shows the other type of pycnial exudate in which the pycnospores dry down forming a thin, shining, orange crust and appear as a mound due to the fact that the pycnidia occur in pustules.

On the trunks of large trees the cankers appear as slightly darkened areas, the lateral margins of which are marked by more or less vertical cracks 3 to 12 inches long. These cracks are the result of tension produced by the drying out of the killed bark. When the bark of the cankered area is pressed it collapses against the wood. Often the cracks outlining the limits of the necrotic area appear to be the only external evidence of the disease, although sometimes a closer examination will reveal the presence of tiny spore horns in the deep crevices of the bark.

### VALSA SORDIDA NKE.

On the trunk cankers of some of the trees *Valsa sordida* was found. It is suspected that this is the perfect stage of *Cytospora chrysosperma* but inoculation experiments are not yet completed to prove this point. The literature shows disagreement as to the species of Valsa that is connected with *C. chrysosperma*. According to Engler and Prantl (1) and Rabenhorst (4) it is *V. sordida* but both Roumeguère (6) and the Tulasnes (7) give *V. nivea* Fr. This matter can be settled only by careful inoculation experiments.

### INOCULATION EXPERIMENTS WITH PYCNOSPORES

Inoculation experiments on poplar cuttings in the laboratory with pycnospores showed the fungus to be a serious wound parasite. Pieces of twigs 4 to 12 inches long and 7 to 21 mm. in diameter were used. The upper end of the cuttings was paraffined to protect the cut surface from infection and to prevent excessive drying. Incisions were made with a sterile scalpel and pycnospores from spore horns applied to the wound. The inoculated cuttings were placed in water in a battery jar which was placed under a bell jar.

Seven cuttings of *P. grandidentata* were inoculated in the manner described above on June 4. Two unwounded stems were placed in the same jar. One twig—incised with a sterile scalpel but not inoculated—was placed in a separate jar. On July 27, as a result of this experiment, 6 of the inoculated cuttings were infected and killed. Figure 2 A shows one of them. The two unwounded cuttings were also infected and killed but the one control remained healthy. Three cuttings of *P. tremuloides*, 11, 12 and 19 mm. in diameter respectively were inoculated in the same manner on the same date. One control (an incision made with a sterile scalpel) was placed with the *P. grandidentata* control. On July 27 the 3 inoculated cuttings were infected and killed while the control remained healthy.

### NATURAL INFECTION IN LABORATORY

Ten cuttings of *P. deltoides* Marsh., ranging from 6 to 10 mm. in

diameter, were brought into the laboratory on June 3 and placed in water in a battery jar. These cuttings began to produce roots but in the course of two or three weeks showed signs of disease. A little later (July 1), they developed the characteristic spore horns of *C. chrysosperma* and finally died. These cuttings were not inoculated and came from a healthy tree which grew at least three quarters of a mile from the diseased area. The source of the spores, by which they were infected, was a collection of cankers on *P. grandidentata* which were lying on a table

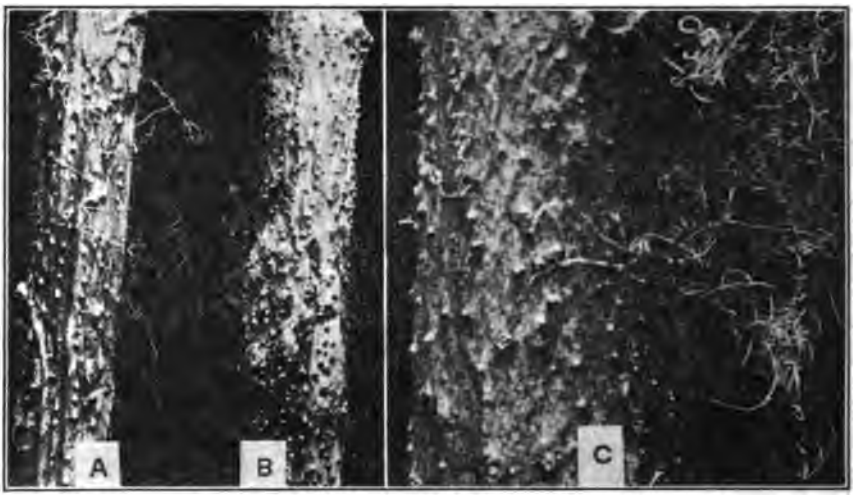


FIG. 3. NATURAL INFECTION ON POPLAR CUTTINGS IN LABORATORY

*A*. On *Populus deltoides* ($\times \frac{4}{3}$).
*B*. On *Populus tremuloides*. ($\times \frac{4}{3}$).
*C*. On *Populus tremuloides*. ($\times$ 3).

in the laboratory. It should be mentioned that the tips of these cuttings were not paraffined. Figure 3 A shows the spore horns on one of these dead cuttings. Thirteen out of the 16 cuttings of *P. tremuloides* became infected in the same manner and were killed. Figure 3 B shows one of these slightly enlarged and Figure 3 C shows another three times enlarged to show the great mass of spore material extruded. The tips of these cuttings were paraffined. From the foregoing it can be seen that this disease would prove serious in any nursery where poplar cuttings are grown.

## SUMMARY

The poplar canker caused by *Cytospora chrysosperma* (Pers.) Fr., a disease hitherto reported only from the Southwest and Northwest, has

been found near Syracuse, N. Y., attacking poplars weakened by fire.

In the diseased area over 68 per cent of the poplars were infected and over 30 per cent killed.

*Valsa sordida* Nke., which may prove to be the perfect stage of *C. chrysosperma*, was found on the trunk cankers of several trees.

Inoculation experiments with pycnospores on cuttings of *P. grandidenta* and *P. tremuloides* resulted in infection and death of the cuttings from the disease.

Cuttings of *P. deltoides* and *P. tremuloides* not inoculated but kept in the laboratory where material producing spore horns was exposed became infected and were killed.

*Populus grandidentata* is a new host for this pathogen.

The writer gratefully acknowledges his indebtedness to Dr. C. C. Forsaith for the photographs for figures 2 and 3. The other illustration is by the author.

DEPARTMENT OF FOREST PATHOLOGY
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SYRACUSE, NEW YORK

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# BRIEFER ARTICLES

## NOTE ON CENANGIUM ABIETIS (PERS.) REHM ON PINUS PONDEROSA LAWS.

JAMES R. WEIR

WITH TWO FIGURES IN THE TEXT

The distribution of this fungus, which has caused serious epidemics in Europe, is not very well known in America, as only a few records of its occurrence exist. A doubtful reference by Schweinitz, occasional mention in fungus and host indices, and a few specimens in various exsiccatae and herbaria comprise its known American history.

### HISTORY

Fink (2) reported this fungus as causing the death and mutilation of eastern white pines (*Pinus strobus*) at Oxford, Ohio. This is the first record of the kind in America. The parasitism of the fungus was not established by Fink, and he suggests that probably other causes, such as drouth and a general impoverished condition of the trees, promoted the activities of the fungus, resulting in death. Although the fungus is shown by the observations of Thümen (5), Brunchorst (1), and Schwartz (4) to be parasitic in Europe, it is not generally recognized as a parasite in America. The fact that it frequently follows drouth and winter injury has led to the conception that it is a secondary fungus with weak parasitic tendencies. Hartig (3, p. 86) held that the disease was a result of drouth.

### OBSERVATIONS

On an area in the Bitterroot Valley, Montana, what appeared to be this fungus was observed for a number of seasons on young *Pinus ponderosa*. On a smaller area of about one acre in extent, especially selected for study, the affected trees, ranging in age from 4 to 8 years, were either dead or dying when first observed. The symptoms of the disease, viz: reddening of the needles and shrinkage of the bark, were most marked in early spring, from March to June, at which time the needles could be easily shaken off. The reddening of the needles first became evident during the winter, from December to February. The disease apparently started in practically all the trees examined, in an infection at the terminal bud. Since the one-year-old twigs alone were infected,

and in some cases were still partially green, infection must have taken place the previous autumn at the close of the growing season. The disease in but a few instances progressed beyond the one-year-old twig, usually ending abruptly at the internode. On some trees every terminal and lateral shoot was dead with only a few green needles on the inner portions of the branches. Such trees, in most instances, had died be-

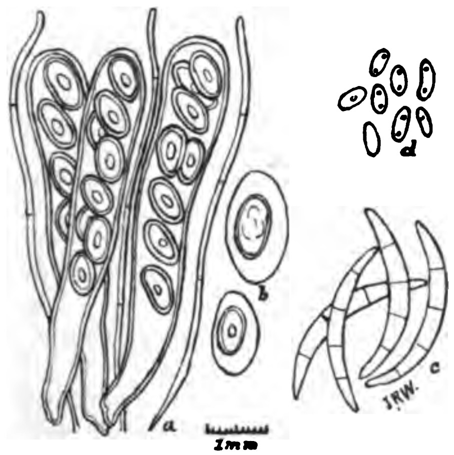


Fig. 1.

Fig. 2.

FIG. 1. SPORES OF CENANGIUM ABIETIS.

a. Asci, ascospores and paraphyses.
b. Ascospores with transparent hygroscopic membrane.
c. Curved septate conidia.
d. Single-celled conidia.

FIG 2. APOTHECIA OF CENANGIUM ABIETIS.

Apothecia on a one-year twig of *Pinus ponderosa*. Photographed by A. S. Rhoads.

fore the end of the growing season. Secondary shoots appeared below the killed portion in some cases, and two 8-year-old trees had apparently thus completely recovered from the disease. The bunched effect of the new shoots gave an appearance of small witches' broom. Two examples, each of nodal and internodal infection, were observed which resulted in the death of the entire branch before the end of the season. That part of the branch beyond the court of infection succumbed more rapidly. The infection in but few cases spread from the terminal shoot into the branches at the upper internode, being checked either by the rapid death of the shoot, or by a very evident resinous impregnation of the bark and wood ahead of the advancing mycelia. This condition was always present in the diseased twigs. The needles first began to

turn red at the point of attachment, later becoming a uniform red color. The twigs were killed rapidly and, late in the autumn, after the fall of the needles or when but few remained, small, black simple or compound pycnidia appeared. These, which agree with the description of *Brunchorstia destruens* Erikss., contained curved 3 to 5 septate spores averaging 23–38 × 3μ (Figure 1, c). Smaller pycnidia, containing simple elongated or elliptical spores measuring 3 × 7μ (Figure 1, d) and which are believed to be the same as those described under the name *Dothichiza ferruginosa* Sacc., were scattered promiscuously among the former. Typical apothecia (Figure 2,) appeared somewhat later. The asci, (Figure 1, a) averaging 9 × 68μ contained 8 hyaline, single celled, elliptical spores with an average dimensions of 4 × 9μ. Under special conditions of preparation, an outer transparent hygroscopic membrane was visible (Figure 1, b). The paraphyses (Figure 1, a) but slightly longer than the asci, were slightly colored, simple, septate, and slightly swollen at the ends. They were mostly confined to the one-year-old twigs and appeared in most cases at the bases of the needle sheaths. The few apothecia observed on older twigs were scattered promiscuously. No fruiting bodies appeared on the needles.

Infection was not uniform throughout the stand, only a tree here and there showing the disease. A count of the reproduction on two acres of typical yellow pine showed an average of 5 per cent infected. The uninfected trees were vigorous and were making the average growth of yellow pine for the site. The dead and infected trees had well developed root systems, and no injuries of any kind, except an occasional healed scar resulting from the tread of grazing animals. There was no tendency toward an epiphytotic condition, nor did the infection during the several seasons it was studied increase or decrease in any degree. Every season a few trees here and there over the area, and otherwise just as vigorous as the uninfected ones, became diseased. The apparent predisposition of certain trees to the disease can not be satisfactorily explained. It is not likely that the condition was caused by an accidental spore distribution.

## INOCULATIONS

The conditions on the area just described are more or less typical of the infections by this fungus wherever it has been observed. The observation that the disease was primarily important on reproduction and was apparently parasitic, led to inoculation experiments to determine the latter point. Four branches on as many 6-year-old trees of *Pinus ponderosa* were inoculated with ascospores taken from diseased trees of the same species. The inoculum was inserted both deep within

the bud scales and in incisions just behind the buds, and protected with fine mesh cheese cloth caps. The inoculations were made on September 10, 1914, in the open at Missoula, Montana, some 40 miles distant from any known infections. Three inoculations out of 16 were successful. In February the needles near the buds began to show a slight reddish color. By midsummer all the needles of the previous year's growth on the 3 infected branches turned red. Later they became brown and could be easily shaken from the branch. During September and October 1915, a few fertile pycnidia, containing single-celled spores, appeared and, later, with the advent of the rainy period, the characteristic fertile apothecia of *Cenangium abietis* developed in considerable numbers on the then dead and shrunken twigs. The controls on the same trees remained free from the disease. The infections were confined to the one-year-old twigs and did not extend to the older parts of the branches. Since the immediate region was uninportant from the standpoint of the host the infections were allowed to remain. Two years later 3 other infections were noted in the clump of pines where the original experiments were conducted. In 1919 the place was again visited and but a single diseased twig could be found. The results of a small number of experiments, indicate the parasitic nature of the fungus, and, what is also of great importance, that the fungus does not appear to be aggressively spreading. However, it is capable of doing considerable damage in nurseries and on transplant areas.

*Cenangium abietis* has been collected on *Pinus ponderosa* in Washington, Oregon and Idaho. It has not been found on any other host.

## SUMMARY

*Cenangium abietis*, the cause of a serious disease on pines in Europe, is here reported for the first time in the western United States on *Pinus ponderosa*. Experiments demonstrate the apparent parasitism of the fungus, a condition not heretofore reported in America.

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BUREAU OF PLANT INDUSTRY,
SPOKANE, WASHINGTON.

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## INVESTIGATIONS OF CRONARTIUM RIBICOLA IN 1920

L. H. PENNINGTON, W. H. SNELL, H. H. YORK AND PERLEY SPAULDING[1]

In the Adirondacks Pennington found that aeciospores were produced in greater abundance and were more widely distributed than in the seasons of 1918 and 1919. This was largely if not entirely due to the more favorable weather conditions during the month of May. Successive generations of uredospores were not so well marked as in the seasons of 1918 and 1919. This fact seemed to be correlated with the more even distribution of rainy weather during the summer months. Although telia were produced in considerable abundance during July and August, few viable sporidia could be found prior to the first week in September. A systematic study in many centers of infection to determine the age of individual infections showed that by far the larger number of them dated back to either 1911 or 1915. An examination of the Weather Bureau records showed that these two years were characterized by unusually prolonged rainy periods in the latter part of the summer. These years were also noted as having an unusually heavy infection of late blight and rot of potato. The studies of 1920 brought out very clearly the fact that repeated defoliation of Ribes by *Cronartium ribicola* causes the death of the infected bushes. In some instances *R. cynosbati*, *R. rotundifolium* and *R. glandulosum* were found to be entirely destroyed in the immediate vicinity of heavily infected pine trees. Where this fact is not taken into consideration, errors may be made in determining the distance from Ribes that infection has occurred in pine.

In 1916 Posey found blister rust infection upon wild Ribes bushes upon one of the Isles of Shoals off Portsmouth, New Hampshire. This season Snell reexamined these islands more closely. Three bushes were found infected in early July upon two different islands. The infections were approximately 7 miles distant from the nearest land and somewhat farther from the Kittery Point infection. All 3 infections were on the northwest side of the islands directly facing Kittery Point. Cir-

[1] Papers presented at meeting of American Plant Pest Committee at Boston, Mass.. November 5 and 6, 1920.

cumstances were such that it seemed practically certain that the spores had traveled from the mainland to the islands in some manner. Carriage by man does not seem to be probable. It seems that wind carried aeciospores the intervening distance of about 7 miles.

Studies by York were as follows: In 1918 one hundred inoculations were made with each of the 3 spore forms—pycnia, aecia and uredinia on the fresh growth of the season of *Pinus strobus*. The inoculations were made in the axils of the leaves, axils of leaf fascicles, terminal buds, and on the internodes both wounded and unwounded. The results are negative. Various experiments were started in 1917 in a swamp with a heavy growth of *Ribes glandulosum* from which the Ribes were eradicated in mid-summer of 1917. The bushes bore a heavy crop of fruit and much of this fell to the ground when the bushes were pulled. By far the largest number of seedlings appeared in the season of 1918, only a small number having developed since that time. In a plot from which all vegetation was removed, a very large number of Ribes seedlings appeared in 1918. On August 22, 1920, it was found that the number of seedlings which remained in these plots varied from 25 to less than 2 per cent of the original number. In case of the larger number, they were considerably sheltered by a stump. Under the various conditions, varying from the above condition of no competition to that of heavy natural competition with other plants, it was found that a very small percentage of the original number of seedlings survived in 1920. Seedlings of 1918 of *Ribes glandulosum* most favorably situated produced their first fruit in 1920. This was exceptional, however. It appears from these experiments that reeradication of Ribes in such situations will not be necessary as soon as it has been believed, and in some cases may not be necessary for a long time. Many inoculations on pines have been made with the various forms of spores of blister rust, but it is still too early to give any statement as to results.

Investigations by Spaulding are briefly: On Block Island plantings were made several years ago of *Pinus strobus*, *P. flexilis*, *P. cembra*, *P. mugho*, *P. sylvestris* and *P. densiflora*. In the spring of 1920 it was found that every tree of *P. flexilis* was badly infected and all but 2 out of 10 bore fruiting bodies. The remaining 2 certainly will bear fruiting bodies next spring if they are still alive. A considerable number of *P. strobus* have also taken the disease but no other species has shown infection. This limited experience indicates that *P. flexilis* is even more susceptible to the disease than is *P. strobus*. This conclusion is borne out by reports from Europe by Moir. Moir also has found *P. koraiensis* infected by the blister rust in Europe. Inoculations upon Ribes here have produced the disease. At Wilmington, New York, the large

pine planting made to determine the distance that infection spreads from Ribes to pine is beginning to show results (fall 1920). Eight or ten different trees were found plainly showing infections, all extending in a single direction, namely, away from Wilmington Notch, through which the prevailing winds of that section blow. The infection has extended at present only about 30 feet. The white and yellow infected spots on pine needles reported by Clinton and McCormick in their inoculations have been found to be frequent in two different localities where natural infection has occurred. Tubeuf in 1917 published results of inoculations similar to those of Clinton and McCormick in inoculating white pines with sporidia from teliospores. In general they fully confirm the American results but it was found that infection in Tubeuf's experiments took place more in the stem itself than in the needles.

Two points brought out by this year's investigations are especially important. They are that Ribes are often killed in intensive outbreak areas, so that some years later the absence of Ribes in such areas cannot be taken as showing that Ribes have been absent previously. This invalidates numerous conclusions which have been made upon this basis. Second, the numerous cases of breaking of the quarantine in the Mississippi Valley show very plainly that this quarantine must be rigidly enforced or the blister rust certainly will become established west of that line. A single diseased shipment will be sufficient.

Previous conclusions that the aeciospores may be blown an indefinite number of miles and cause infection of Ribes are borne out by this season's work.

## PHYTOPATHOLOGICAL NOTES

*Chlamydospores of Fomes officinalis in nature.*—The references to the occurrence of secondary spores of Hymenomycetes in nature, chiefly upon the fruit bodies, are quite numerous, especially in European mycological literature of the latter part of the past century. Since that time several workers have suggested the possibility of dissemination of wood-destroying fungi by means of these secondary spores—oidia, chlamydospores, conidia, etc. This possibility is as yet unproved and while many of our wood destroyers form secondary spores in agar cultures, such spores occurring naturally have been reported for very few species.

While working at Bald Mountain, Humboldt County, California, in the fall of 1918, the writer found chlamydospores of *Fomes officinalis* formed on rotten wood. A heavy growth of mycelium was noticed upon the sawn end of a Douglas fir badly decayed by *Fomes officinalis*. The mycelium was found not only on the cross section of the bole, but also in rifts within the rotted interior. No opportunity was offered for examination of this mycelium until it was rather old and had been frosted several times. At that time the mycelium and what appeared to be chlamydospores were not in good condition. Material from this tree was cultured on malt agar in connection with investigations being carried on at that time and examination of these cultures later showed an abunbance of chlamydospores resembling those described by Faull[1] from his cultures. These chlamydospores were found to germinate readily.

In the summer of 1919, at the request of the writer, Dr. A. S. Rhoads sent two specimens of wood of two trees of *Pinus ponderosa* badly decayed by *F. officinalis* from Massack, Plumas County, California. These were examined in the fall at Madison, Wisconsin. Chlamydospores were found in the loose mycelium growing on the surface of the pieces of rotted wood and in the cracks, but not in the thick mycelial mats which are commonly present. Attempts to germinate the spores were unsuccessful, perhaps because of prolonged drying, as the material was not examined until four months after it had been received. As far as can be

[1] Faull, J. H. Fomes officinalis (Vill), a timber destroying fungus. Trans. Roy. Canad. Inst., **11:** 185–209. *8 pls.* 1916.

ascertained, the finding of the chlamydospores upon the vegetative mycelium in nature has not previously been reported.

These chlamydospores are similar to those found in culture. They are colorless, globoid to ellipsoid (or fusiform according to Faull), the latter usually with papillate apex and truncate base. Their size is variable, the limits being 5.5–9 × 5.5–9μ. The contents are granular

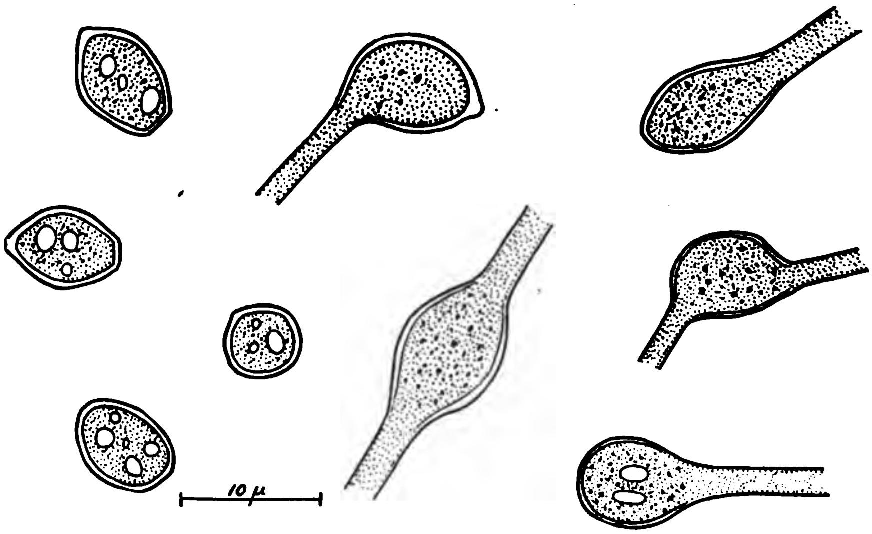


FIG. 1. CHLAMYDOSPORES AND HYPHAL SWELLINGS OF FOMES OFFICINALIS FOUND IN BADLY DECAYED WOOD OF PINUS PONDEROSA.

and oil globules are common. They occur singly and terminally. Terminal and intercalary swellings of the hyphae are common (Figure 1), but nothing was observed to show that the intercalary swellings matured to chlamydospores.

In addition to the chlamydospores occurring in cultures of *F. officinalis*, Faull also reports finding chlamydospores in the crust of all the fruit bodies of this fungus which he examined. These latter, however, are different in size, shape, color, and formation from those formed in culture. They are described by Faull (p. 201) as formed in chains by further septation of the septate hyphae, with or without enlargement, followed by a thickening of the walls. They measure 2–7 × 2–6μ, are "irregularly spherical to elongated and in color from hyaline to yellowish brown," the latter color appearing as the spores mature.

Faull expressed the belief that the chlamydospores in the fruit bodies are a means of propagating the fungus. While the chlamydospores found upon the wood were not germinated, it seems reasonable to assume

that fresh chlamydospores would be viable, inasmuch as they are apparently identical with those developed in cultures, and that propagation of this fungus in nature by means of its chlamydospores is possible.—WALTER H. SNELL.

*A chisel forceps.* Difficulties are encountered with scalpel and forceps in preparing fragments of infected wood for culturing on artificial media. The thin handle of the scalpel is objectionable when considerable pressure is needed to pry the fragments loose. Some difficulty is also experienced in transferring the fragment to the media containers. Interchanging the scalpel for the forceps is an interrupted operation and requires additional time for sterilization. One objection to the interrupted operation is the additional time during which contamination can take place. The instrument, (Fig. 1) described below, with cutting edge and forceps combined, is designed to replace the ordinary scalpel and forceps for this type of work.

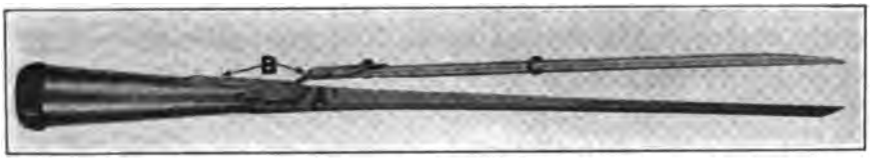


FIG. 1. A CHISEL FORCEPS.

The chisel forceps is made by soldering or brazing to the flat side of the shank (Fig. 1 A) of a good grade of wood-cutting chisel a strip of spring metal (Fig. 1 B) to which is attached a metal rod about 5¾ inches long flattened at the free end (Fig. 1, C). The chisel is about 8½ inches long and has a ¼ inch cutting edge. The wooden handle of the chisel is replaced by a short rounded wooden plug which gives a good surface for applying pressure with the palm of the hand.

The instrument grasped in the right hand is first sterilized by dipping in alcohol and flaming, the chisel point is then forced into the infected wood, a fragment is pried loose, is then grasped between the chisel point and the movable arm and transferred to the medium within the glass container where it is easily plunged to the required depth at the desired spot in one operation.

This instrument can be constructed to meet the special needs of other phases of plant pathology. A wood-carver's gouge with a ⅛ inch cutting edge or some other tool substituted for the chisel would prove useful in detaching fragments of inoculum from diseased tissues of potato, cabbage, carrot, and other crop plants.—ERNEST E. HUBERT.

*Polyporus schweinitzii Fr. on Thuja plicata.* The heart wood of *Thuja plicata* (western red cedar) is subject to three common and distinct types of decay, all of which are of economic importance. A uniform light yellow or brown, laminated, carbonizing trunk and butt rot caused by *Poria weirii* Murrill, is very common throughout the range of the tree. A dark brown, crumbly, carbonizing, pocket, and ring rot is also very common and destructive, but has never been definitely connected with any known wood destroying fungus. It has been incorrectly referred to *Polyporus schweinitzii.* A uniform, brown, carbonizing butt rot breaking up into rectangular blocks has been attributed to *Polyporus schweinitzii* by various observers, but sporophores have never been reported as associated with this decay. Recently a single specimen of *Polyporus schweinitzii* Fr. was found associated with its typical decay in a root of western red cedar near Priest Lake, Kaniksu National Forest, Idaho. The brown, cubical, carbonizing rot of this fungus was uniform throughout the heart wood of the base of the tree, and extended upward for a distance of about four feet. The sporophore had its origin directly in the diseased wood. This wood after exposure produced the mycelium of this fungus. This is the first authentic record of the collection of a sporophore of this fungus associated with its decay on western red cedar.

The lighter color of the decayed wood, its uniformity throughout the affected area, absence of any tendency to form pockets or streaks, and the large size of the individual cubes of decayed wood, makes it doubtful if *Polyporus schweinitzii* is the cause of the unknown, brown, pocket rot above mentioned. The appearance of the latter is very similar to the decay caused by *Polyporus amarus* Hedgcock in *Libocedrus decurrens*, but sporophores of this species have not been found on western red cedar. In view of this fact, and the rarity of *Polyporus schweinitzii* on cedar, it is believed the identity of the common brown pocket rot in this tree is as yet undetermined.

*Fomes pini* (Thore) Lloyd attacks the western red cedar on isolated areas, but it is not a common cause of decay. *Fomes annosus* Fr., *Polyporus sulphureus* (Bull.) Fr. and *Armillaria mellea* Vahl occasionally attack the living tree, but with the exception of the last named species, which also attacks and kills young trees, they are not of much economic importance as regards the destruction of merchantable timber.—JAMES R. WEIR.

*The age of brown-rot mummies and the production of apothecia.* It has been supposed generally that the ascogenous stage of the American form of the brown-rot fungus (*Sclerotinia cinerea*) affecting peaches, plums and other stone fruits does not appear except on mummied fruits

which are more than one year old, but in the spring of 1921, the writer obtained apothecia from mummied fruits of the 1920 crop of both plums and peaches. During the summer of 1920, plums and peaches affected with brown-rot were collected and placed on the ground in a situation remote from plum and peach trees. The diseased fruits were of the current year's crop, great care being used to select only those which were still plump and juicy in order to avoid any chance of selecting a mummied fruit of a previous year. The rotting fruits were placed on the ground in a shaded situation where there was no chance of other decayed fruits being present. In all eight hundred plums and seventy-five peaches were used in the experiment. In March, 1921, forty of the plums and five of the peaches were found to be producing apothecia, varying in number from three to twenty-one for each fruit. Morphologically these apothecia agreed in every way with those of the American form of *Sclerotinia cinerea*. Cultures from single spores produced typical mycelium and spores and could not be told from stock cultures of the American form of the brown-rot fungus.—JOHN W. ROBERTS.

*Summer field meeting of cereal pathologists.* Plans for the forthcoming summer field meeting of cereal pathologists and others interested in cereal crop improvement have been completed. Accordingly it has been arranged to call the meeting at University Farm, St. Paul, Minn., and the following itinerary has been announced:

*Tuesday,* July 19—Meet at University Farm.

*Wednesday,* July 20—Trip through environs of Minneapolis and St. Paul. Lunch at the Fruit Farm near Lake Minnetonka.

*Thursday,* July 21—Minneapolis: visiting flour mills and grain elevators; field trip near Twin Cities; laboratory and nursery inspection at University Farm. Leave Minneapolis for Fargo N. D.

*Friday,* July 22—Visit College Farm and laboratories. Field trip in vicinity of Fargo.

Invitations have been sent to several European, South American, and other foreign plant pathologists, and it is anticipated that the meeting will be the most representative of all the summer cereal field conferences yet held in the United States. Those planning to attend this meeting are requested to notify Dr. E. M. Freeman, University Farm, St. Paul, Minn.

*Personals.* Dr. D. Atanasoff, formerly graduate student at the University of Wisconsin, after spending a year at the Biologische Anstalt, Dahlem and at other institutions in Germany has accepted a position in the laboratory of Prof. Dr. H. M. Quanjer of the Phytopathological Institut at Wageningen, Holland.

# THE COOPERATIVE POTATO SPRAYING PROJECT: PROGRESS REPORT FOR 1918, 1919, AND 1920.

G. R. Bisby

The cooperative potato spraying project is one of the problems for cooperative work undertaken by American plant pathologists under the auspices of their War Emergency Board and Advisory Board. The general leadership of this project, and the responsibility for this report, has been assumed by G. R. Bisby, Agricultural College, Winnipeg, Canada (Formerly at the Minnesota Agricultural Experiment Station).

Bordeaux mixture is commonly applied to potatoes in regions in which late blight occurs or threatens each year. Increased yields result in some areas even when late blight is absent. For many regions, however, plant pathologists do not know just what recommendations to make to potato growers regarding the use of Bordeaux mixture and other fungicides.

The War Emergency Board of American Plant Pathologists considered it important that cooperative work be undertaken on a potato spraying project, and the writer was asked in the latter part of June, 1918, to serve as leader. Letters were at once sent out to pathologists in order to place the proposition before them, with inquiries as to past results of spraying potatoes, and a request for suggestions. Considerable information was received in response to these letters.

The Advisory Board of Pathologists decided that this project, lying between experimentation and demonstration, was a favorable one for continued cooperative effort. G. R. Lyman called a meeting of interested pathologists at Chicago on February 15th, 1919, and the spraying project, among others, was discussed. It was decided to draw up a definite field experiment, with the use of standard equipment, spray materials, and methods of application, with a view of obtaining comparable results and an idea of the optimum spraying schedule in the various localities. This field plan, devised largely by C. R. Orton, is partially given below, and was submitted in 1919 to various workers for their reference, although it was realized that few would be able to undertake the full project.

Early in 1920, this project was again brought to the attention of many of the pathologists. With the beginning of 1921, it was decided to publish this report of the work that had been done by those cooperating.

It was considered worth while also to include a brief summary of the present status of spraying throughout the United States and Canada. A summary for each state and province was accordingly submitted to the proper worker with a request that he correct or amplify the statement as applying to his region. This report is, therefore, a review of the problem for many regions, and includes considerable new data that several have been able to add. The greatest credit is due to the various pathologists and others for the generous way in which they have contributed data for the summary, and for the hearty cooperation that practically every worker has manifested in this project. The leader has endeavored to function merely in providing a clearing house for the scattered results. Thanks are due to Messrs. G. R. Lyman, E. C. Stakman, and C. R. Orton for ideas and help of various kinds.

### PLANS OF THE PROJECT

The necessity for working in cooperation with the entomologists in potato spraying work is becoming more evident. Leaf hoppers and aphids are now known to cause or to transmit diseases, and the control of the flea beetle by Bordeaux mixture is also of interest to entomologists. The use of the principles developed by agronomists in field technic must be taken into consideration, in the provision of sufficient checks and replications as well as the use of uniform fields and methods. Experiments in commercial fields are particularly valuable in that larger areas can usually be sprayed, and practical grower's equipment and conditions can be taken into consideration. Sufficient checks should, of course, be left, and these arranged so as to give comparable results; e. g., eight rows sprayed, then four rows left unsprayed, rather than one acre sprayed and another acre left unsprayed. Experimental spraying on a small scale is, of course, valuable, and can often be used to advantage in deciding local questions.

The potato spraying project was brought to the attention of the workers during the three years by letters inquiring as to whether opportunity or need existed for testing out the effect of Bordeaux mixture with the suggestion that such results as were secured might be rendered of added value by comparison with other data from similar regions or under similar conditions. No attempt was made to dictate what should be done, and even excessive "organization" of the project was avoided. An outline of the field experiment previously mentioned was, however, sent out for reference in 1919 and 1920, including the recommendations that standard machines capable of maintaining high and uniform pressure be used. A 4–4–50 Bordeaux mixture was suggested, made as follows: fill the tank one-third full of water; add the required

amount of stock solution of lime; fill the tank two-thirds full of water to mix the lime thoroughly; add required amount of stock solution of copper sulphate; and fill the tank with water. This is economical of time and labor unless special elevated tanks have been rigged up for the purpose. Arsenate of lead or other poison should be applied to each plot upon the first appearance of biting and chewing insects.

An outline for the taking of field data was submitted, including records of soil type, dates of planting and spraying, occurrence of diseases and insects with dates and prevalence, pressure used, yield, costs, etc. It was noted that the field might be of any size; but an acre field was suggested, 360 feet by 121 feet. The field might be divided into 30 plots, each plot consisting of 4 rows of potatoes (see table 1). The letters indicate the time each plot is to receive a particular spray; e. g., A—1st spray, E—5th spray, etc. It was suggested that the plots be sprayed at regular intervals beginning when plants were 5 inches high, and repeating every 10 days. It was recommended for experimental purposes that as many applications be made as the season might permit. Plots 5, 11, 17 and 23 are checks to receive only poison for insects. Various plots should indicate the importance of spraying in different parts of the season.

In many cases, it would not be necessary to apply the ten sprays listed on the field plan; and the sprays J, I, etc. could be omitted without affecting the general value of the plan.

The following reports on the status of the use of Bordeaux mixture in the various states and provinces are listed by regions. Where publication of results has been made, a very brief summary is included—the references to bulletin numbers referring to the bulletins of the agricultural experiment station in question. The imperial gallon, used in Canada, is ¼ larger than the U. S. gallon; a Canadian reference to 4–4–40 Bordeaux should be interpreted 4–4–50 in the United States.

## SUMMARY OF RESULTS AND STATUS OF THE USE OF BORDEAUX MIXTURE ON POTATOES

*Canada: Work of the Dominion Department of Agriculture in Eastern Canada.*—G. E. Sanders and his co-workers, particularly A. Kelsall, have recently developed in Nova Scotia a copper dust. They have tried out the "5-2" formula on potatoes, the figures referring to the percentage of metallic copper and metallic arsenic respectively. Twenty pounds of copper sulphate, dehydrated and ground fine, forming 12½ lbs. powder; 7½ lbs. dry arsenate of lime, containing 40 per cent $As_2O_5$, and 80 lbs. of hydrated lime are mixed. This dust was found to stick well, and when moisture strikes the leaf, a blue Bordeaux is produced. At Frederickton, N. B., the dusted plot yielded 396 bu. per acre; 4–4–40 (4–4–50, U. S. gallon) Bordeaux, 407 bu.; check, 238 bu. At Truro, N. S., dust, 744 bu. per acre; Bordeaux plus poison, 652 bu.; check, 550 bu. (Proc. Ent. Soc. Nova Scotia, **1918**: 32–37, 1919). Their report for 1919 (l. c. **1919**:

TABLE 1.

*Plan of Field*

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | | A | A | A | A | A | | A | A | A | A | | | | | | | | | | | | | | | |
| | | | | | B | B | B | B | B | | B | B | B | B | B | | | | | | | | | | | B | | | |
| C | | | C | | | C | C | C | C | | C | C | C | C | C | | C | | | | | | | | | | | | |
| D | D | | | | | | D | D | D | | D | D | D | D | D | | D | D | | | | | | | | D | | | |
| E | E | E | E | | | | | E | E | | E | E | E | E | E | | E | E | E | | | | | | | | E | E | E |
| F | F | F | | | | | | | F | | F | F | F | F | F | | F | F | F | F | | | | | | F | F | F | F |
| | | | G | | | | | | | | G | G | G | G | G | | G | G | G | G | G | | | | | | | G | G |
| | | | | | | | | | | | | H | H | H | H | | H | H | H | H | H | | H | | | H | | | H |
| | | | I | | | | | | | | | | I | I | I | | I | I | I | I | I | | I | I | | | | | |
| | | | | | | | | | | | | | | J | J | | J | J | J | J | J | | J | J | J | J | | | |

77–94, 1920) gives further results. The yields of potatoes obtained in 1919 average somewhat less from dust than from Bordeaux, but insects well controlled by dust. Late blight control not perfect if less than 5 per cent of metallic copper is used in the dust. Some evidence that the "stimulating effect" of the dust on the plant is greater than that from Bordeaux. Sanders and Brittain consider (Proc. Ent. Soc. N. S., **1916**: 55–64, 1917), that arsenic compounds have their efficiency reduced when added to Bordeaux; but that sodium compounds increase the effectiveness of poison, perhaps by rendering the leaves more appetizing to insects. Sanders and Kelsall recommend equal parts of $CuSO_4$ and lime in wet Bordeaux for potatoes; but find a mixture containing 3 to 5 times as much lime as copper valuable for apple (l. c., **1918**: 69–75. 1919; see also pp. 51–61). Other observations by the same workers in Agr. Gaz. Can. **7**: 10–12, 1920, and Proc. Ent. Soc. N. S., **1919**: 21–33. 1920.

Wm. Blair reported in 1892 some average increase at Nappan, N. S., from spraying potatoes with about a 3–2–11 Bordeaux. (Canada Cent. Exp. Farm. Report **1892**: 187). Other data in the reports for **1893**, p. 222, and for **1900**, p. 335. W. T. Macoun reports (l. c. **1904**: 131–132; Bull. 49) an increase of 92½ bu. per acre as a result of 4 and 5 applications of Bordeaux at Ottawa in 1901, 1902, and 1904. He also found (l. c. **1905**: 111–121) Burgundy mixture 6–7½–40 did not injure potato leaves; but that the results were hardly as good as from Bordeaux. Other data in the Central Exp. Farm Reports **1892**: 161–164; **1908**: 126; **1910**: 251–284; **1916**: 1147–1149.

H. T. Güssow writes that the Dominion Department of Agriculture has for some years been devoting efforts to bring about the general use of thorough spraying in the Maritime Provinces and in Quebec.

*Prince Edward Island.*—Late blight common. P. A. Murphy reported (Can. Dept. of Agr., Circ. 10, 1916; Agr. Gaz., Can. **4**: 942, 1917) 97 bu. per acre increase from 5 applications of Bordeaux in 1915. In 1916, no increase in yield from spraying; but rot much reduced. T. Ross reported (Agr. Gaz., Can. **2**: 334, 1915) about half the growers used Bordeaux. G. O. Madden writes that there is no data as to the effect of Bordeaux when late blight is absent.

*Nova Scotia.*—Late blight common, first appearing after 1877. Scarcely any of the larger growers now attempt to grow the crop without spraying (R. L. Fuller, Agr. Gaz., Can. **2**: 334, 1915). See data previously given.

*New Brunswick.*—Faithful use of Bordeaux necessary. (J. B. Daggett, Agr. Gaz., Can. **2**: 334, 1915). B. Baribeau writes that he has no data as to the value of Bordeaux in the absence of late blight. See also data previously given.

*Maine.*—W. J. Morse reports late blight usually present, often serious. Early blight and tipburn common, more particularly in the southern part of the state. Tipburn apparently physiological. Necessity of spraying with Bordeaux abundantly proved (Me. Bulls., 73, 87, 98, 112, 149, 164, 169). Iron sulphate decreases yield (Bull. 236). Bordeaux quite effective as a repellant against flea beetle (Bull. 211). Prepared or hydrated lime found satisfactory (Bull. 98).

*New Hampshire.*—Late blight common, tipburn common, early blight not serious. Bordeaux pays. O. R. Butler reports ratio of copper sulphate to lime must be about 1: ½ if satisfactory adhesiveness is to be obtained. An 8-4-50 Bordeaux applied every two weeks gave superior protection to a 4-4-50 mixture applied weekly in 1919. (See Pl. Dis. Bull. Suppl. 10, 1920. N. H. Sta. Circular 22, 1920; Phytopath. **4**: 125, 1914 and **9**: 431, 1919, N. H. Bull. 192, 1919 and Circ. 15, 1914, for physical and chemical studies). Bulls. 22, 27, and 45, by H. H. Lamson, dealt with increased yield from spraying.

*Vermont.*—B. F. Lutman writes that the potato crop in Vermont can be increased 15 to 25 per cent, in the absence of late blight, by keeping the plants covered with Bor-

deaux from early July for two months, necessitating at least four sprayings. Results more pronounced on late than on early potatoes. Bulletin 159 summarizes results of twenty years spraying, begun by L. R. Jones, during which an average of 105 bu. per acre increase was obtained. See also Bulletins 24, 40, and Annual Reports 9, 15, 16, 17, 18. Bulletins 196 and 214 and Potato Magazine, July, 1918, give further data, especially effect on leaves, on tipburn, etc. Advantage of spraying thoroughly established.

*Massachusetts.*—A. V. Osmun reports that 4-4-50 Bordeaux for early applications, and 5-5-50 for later sprayings give good results in control of late blight. Carefully conducted experiments in potato spraying have not been performed. Bordeaux is recommended to, and commonly used by, growers.

*Rhode Island.*—Director B. L. Hartwell reports published discussion of Bordeaux for potatoes in Bulletin 38, 1896, and in third Annual Report of Station, 1890, and results of tests given in Bulletin 111, 1906. Bulletin 111 gives a comparison of varieties as to resistance to late blight, and effect on some fifty varieties from spraying five as compared with four times.

Since 1905, various unpublished data have accumulated, which were kindly submitted by Director Hartwell, and are here briefly summarized. In 1906, about seventy-five varieties of potatoes were grown, half the rows sprayed five times with Bordeaux, half with insecticide only. The varieties were classified into two groups, higher yielding and lower yielding; the former averaged 254.7 bu. per acre where sprayed, 160.1 bu. per acre without Bordeaux; the latter 144.1 and 97.3 respectively, Late blight present; but appearance was retarded on sprayed areas, and late varieties in general showed the disease later than did the early varieties. New Queen potatoes also planted at different dates and left unsprayed to see if degree of maturity had any influence in the time of appearance or severity of late blight. Results as follows:

TABLE 2.

*Effect of maturity on late blight attacks*

| DATE OF PLANTING | YIELD ON SEPT. 17 | PERCENTAGE OF FOLIAGE ATTACKED BY LATE BLIGHT | | | |
|---|---|---|---|---|---|
| | | JULY 31 | AUG. 2 | AUG. 4 | AUG. 9 |
| Apr. 28 | 188 bu. | 10 | 20 | 75 | 90 |
| May 5 | 153 " | 10 | 20 | 75 | 95 |
| " 12 | 147 " | 10 | 20 | 70 | 85 |
| " 19 | 104 " | 3 | 10 | 60 | 85 |
| " 26 | 91 " | 2 | 5 | 55 | 80 |
| June 2 | 35 " | 1 | 5 | 50 | 85 |

New Queen potatoes sprayed twice with Bordeaux yielded 222 bu. per acre; sprayed four times, 241 and 239 in two plots; not sprayed, 122 and 98 bu. per acre.

In 1907, about seventy-five varieties grown as before, but late blight almost absent. Four sprayings with Bordeaux nevertheless gave 15 per cent increase in yield of potatoes over two ounces. Over six hundred varieties from J. R. Lawrence, East Raynham, Mass., grown without spraying to test resistance to blight; but no progress because of absence of the disease.

In 1908, about four hundred and seventy-five varieties planted on April 29th and 30th, and dates recorded on which leaves had turned brown entirely because of blight. By August 28th, only the varieties, Arabella, Fidelio, Gov. Folk, Prof. Wohltman

Scottish Triumph, Scott's No. 8, No. 10, and No. 43, Table Talk, The Bruce, Violette au Claire, Warrior, and Queen were not entirely brown. Although certain of the varieties yielded over 250 bu. per acre, Table Talk (123 bu.) and Warrior (97 bu.) were the only ones of the above list which yielded over 60 bu. per acre.

In 1909, only about fifty of the varieties were planted, many having been discarded on account of the small yields. An estimate was recorded of the percentage of blight on August 20th. Those varieties then showing less than 10 per cent of blight, together with their total yields of potatoes at harvest time were as follows: Epitomist Bolgiani, 87 bu., Ensign Bagley, 140 bu., Wild Potato from Mexico, 28 bu., Geante Blanche, 165 bu., Junior Pride, 68 bu., Old Hemlock, 78 bu., Pearl of Savoy 61 bu., Pat's Choice, 131 bu., Piqua Chief, 95 bu., Purple King, 30 bu., Richter's Imperator, 19 bu., Rural Blush, 181 bu., Uncle Sam, 85 bu., White Flyer, 209 bu., Whitten's White Mammoth, 168 bu., and Violet, 70 bu. The maximum yields were of McCormack, 303 bu. (15 per cent of blight) and World's Fair, 353 bu. (10 per cent of blight). At least 90 per cent of blight was recorded on August 20th, on the following varieties: Daisy, Merrill, Orguil du Marche, Presbey's 66, Sport of Admiral Foote, and Scotch Rose.

There is no record that the work on selection of blight-resistant varieties was continued later than 1909.

Other observations as follows: in 1906, application of dust Bordeaux, wet, gave a yield of 139 bu. per acre; dust Bordeaux, dry, 165 bu., regular Bordeaux, 234 bu., and without fungicide, 124 bu. In 1914, "Bug Death" applied, 169 bu. per acre, Bordeaux, 175 bu. In 1916, nearly twelve inches of rain in July. With Insecticide and two or three sprayings with Bordeaux, 74 bu. per acre, with Insecticide and about ten applications of Bordeaux, 106 bu. In 1917, Insecticide only, 293 bu. per acre; Insecticide and Bordeaux, 295 bu. per acre. In 1918, Insecticide and two or three applications of Bordeaux, 302 bu. per acre; with Insecticide and about ten sprayings with Bordeaux, 301 bu. per acre. In 1919, blight could not be controlled because of a total of sixteen inches of rain in August and September.

While in certain years no particular increase has occurred, it is evident that the application of Bordeaux in Rhode Island pays with late potatoes because of the danger from late blight and the increase in yield usually resulting from spraying. Many growers believe, however, that spraying is less necessary with the Irish Cobbler type.

*Connecticut.*—G. P. Clinton has published (Ann. Rep. **1915**: 487, 1916) thirteen years' results in which an average increase from spraying of 38 bu. per acre was obtained in various experiments. Average in blight-free years, 29 bushels increase. Results for 1916 in Ann. Rep. for **1916**: 355–364, 1917; and later results under growers conditions in which less favorable results were obtained are given in bulletin 214, 1919. Clinton reports, "On the whole, farmers in this state have not made a practice of spraying for blight, partly because there are no districts devoted largely to potato growing. Summing up experience for past sixteen years: (1) It certainly does not pay to spray early potatoes. (2) If I were growing late potatoes as a special crop, I would practice spraying, although on the average they do not suffer severely from blight once in five years." Dr. Clinton also considers that spraying might be more advantageous in northern Connecticut. He finds home-made 4-4-50 Bordeaux better than Pickering's solution, or than barium water Bordeaux. Spraying is not likely to become general in Connecticut. In dry years, yield of sprayed fields is sometimes reduced by trampling of vines. Better results from three or four thorough hand sprayings than from power machines going over fields six or seven times. The latter is the more common practice, however.

*Quebec.*—Late blight common. Bordeaux tested in 1919 in 6 fields in Pontiac County

gave average increases of 60 bu. per acre from 4 sprayings; in 1920, 3 fields sprayed 5 times gave average increases of 150 bu. per acre, and rot was greatly lessened (C. H. Hodge, Agr. Gas. Can., 7: 959, 1920). Tests in 60 fields in 40 counties gave an average of 35 per cent greater yield from poisoned Bordeaux than from poison alone in 1919 (G. Maheux, Que. Soc. Prot. Plants Ann. Rep. 12: 43–46, 1920).

*Ontario.*—C. A. Zavitz reports (Bull. 239) an average increase of 18.7 bu. per acre from 18 tests during 3 years from spraying the tops and bottoms of the leaves 3 times with Bordeaux. Late blight rot was quite serious 5 years, somewhat troublesome 5 years, and practically absent 16 years during 26 years at Guelph. Bordeaux decreased amount of rot in the crop. Relative resistance of potato varieties to rot given. Prof. J. E. Howitt reports Bordeaux recommended, and progressive growers spray each year with apparently good results even in absence of blight on account of preventing tipburn and increasing or lengthening the growth of the plants. Results obtained at Ottawa by Dominion workers previously mentioned.

*New York, Geneva Station.*—F. C. Stewart and co-workers have fully demonstrated the value of spraying in New York as a preventive of late blight, and they find spraying pays in the absence of late blight by lessening flea beetle and tipburn injury. Lime sulphur injurious. See bulletins 123, 221, 241, 264, 267, 279, 290, 307, 311, 323, 338, 349, 379, 397, 405, 421. Experiments for ten years at Geneva and Riverhead, and many farmers' tests, gave average increases of from 25 to 97.5 bu. per acre from spraying (Bull. 349).

*New York, Cornell Station.*—The Extension Department has carried on potato spraying demonstrations in a total of forty-two fields in Allegany, Cortland, Erie, Fulton, Monroe, Nassau, Oneida, Ontario, Otsego, and Steuben counties in 1918 and 1919. For these two years Chupp reports the average yield of the sprayed fields was 240 bu. per acre, of the unsprayed fields 190 bu. per acre. In 1918, no blight occurred; yet an average of twenty-eight fields in seven counties gave an increase of about thirty bushels per acre from applying Bordeaux under growers conditions. In 1920, Bordeaux applied to 57 fields in 11 counties gave an average yield of 277 bu. per acre; the checks yielded 206 bu. per acre. Late blight severe. The Department is also trying the effect of dusting with Sander's copper-lime dust. On the average, as good results were obtained during 1920 in yield and in control of blight as were obtained from Bordeaux sprayed rows.

*New Jersey.*—Late blight absent 1913 to 1917, present 1918 to 1920; early blight rather serious, tipburn common. H. C. Lint (Ann. Reps. 1915 and 1916) reported good results from Bordeaux. Sulphur dust he found of less value than Bordeaux. M. T. Cook (Circ. 105) reported six year's results in which the effect of Bordeaux on Cobblers and Giants varied. During 1919 and 1920, W. H. Martin performed experiments. Fom his data, the following brief summary is made. In 1919, main crop Cobblers grown in Salem Co. were sprayed five times with a traction sprayer. No late blight, but considerable early blight and tipburn. Plants began to die on July 7th. By July 22nd, an average of 89 per cent of the leaves were dead on the check plots, but only 44 per cent were dead on the 5-5-50 Bordeaux plot, and 27 per cent on the commercial zinc-Bordeaux plot. The latter spray was made up to about the strength of the home-made Bordeaux. Checks sprayed with lead arsenate. Average yield of three Bordeaux plots, 265.4 bu. per acre; of three zinc-Bordeaux plots, 268.6 bu. per acre; of four checks, 216.0 bu. per acre. Increase from spraying in the absence of late blight, about 50 bu. per acre. Late crop Cobblers planted July 1st, on level loam field in Salem Co. were sprayed September 12th, 19th, 29th and October 9th with traction sprayer giving 150 lbs. pressure, three nozzles to row. Check plots unsprayed. Late blight

first observed in check plot Sept. 29th; and by Oct. 9th, 75 per cent of the leaves in the check plots were infected with late blight. while by Oct. 21st, only 3 per cent of the leaves were dead on the sprayed plots. Unsprayed plots ranged from 120.7 to 140.9 bu. per acre, with an average for ten plots of 132.7 bu. per acre; sprayed plots ranged from 172.2 to 196.2 bu. per acre, with an average for nine plots of 183.4 bu. per acre, an increase of about 50 bu. per acre for late crop Cobblers in the presence of late blight. In 1919, main crop American Giants in Monmouth Co. were sprayed four and five times, some at 150 and some at 250 lbs. pressure, with 5-5-50 Bordeaux, the checks being sprayed with lead arsenate. Some early blight and tipburn present. Six check plots gave an average yield of 258.7 bu. per acre; three interspersed Bordeaux plots sprayed four times gave an average of 239.4 bu. per acre, an average loss of 19.3 bu. per acre from spraying. In another series, three plots sprayed five times with Bordeaux at 150 lbs. pressure gave an average yield of 215.2 bu. per acre; six corresponding checks, an average of 269.9 bu. per acre, a loss of 54.7 bu. per acre from spraying. Three plots sprayed five times at 250 lbs. pressure gave an average yield of 226.2 bu. per acre; six corresponding checks averaging 255.6 bu. per acre, a loss of 29.4 bu. per acre from the use of Bordeaux on American Giants. No late blight on the Giants. In 1920, Giant variety (main crop) in Middlesex Co., sprayed six times with 5-5-50 Bordeaux applied with three nozzles per row at 150 lbs. pressure gave an average yield of 246.6 bu. per acre; lead arsenate checks yielded 261.7 bu per acre. Late crop Giants in Salem Co. similarly sprayed with Bordeaux five times yielded 178.0 bu. per acre; unsprayed check 150.4. Late blight present: on October 18th, 62 per cent of leaves dead on check plots, 10 per cent on sprayed plots. Main crops Cobblers in Salem Co. sprayed five times gave yield of 281.8 bu. per acre with 5-5-50 Bordeaux, 226.0 bu. per acre with 4-4-50, and 260.3 bu. per acre on lead arsenate check. No late blight. Late crop Cobblers in Salem Co. sprayed five times yielded 199.3 bu. per acre; unsprayed check 163.9 bu. per acre, arsenate of lead check 175.2 bu. per acre. On October 18th, 92.5 per cent of the leaves dead on check, 9.0 per cent on 5-5-50 Bordeaux plot, 68.0 per cent on arsenate of lead plot. Most of this dying from early blight and tipburn, though considerable late blight was present.

It evidently pays to spray Cobblers in New Jersey, but not Giants, except in the case of the late crop which may suffer from late blight. Actual decrease in yield from spraying main crop Giants.

*Pennsylvania.*—C. R. Orton has helped greatly with the cooperative spraying project, supplying many ideas, and with E. L. Nixon through the Extension Service of the Pennsylvania State College has obtained a mass of data as to the value of spraying in Pennsylvania. Late blight sometimes present, early blight and tipburn rather serious. Remarkable increases from Bordeaux even in absence of late blight (See Pot. Mag., Jan., 1920). In 1918, thirty-two demonstrations of spraying were held in twelve counties, a total of 314 acres being sprayed an average of five times at an average cost of $8.65 per acre, and resulted in an average increase of 34.8 bu. per acre. In 1919, 224 demonstrations were held in twenty-three counties, spraying a total of 1,787 acres an average of 5 times with an average increase of 42.9 bu. per acre. worth in 1919 $58.50, at a cost of $9.00 per acre. In 1920, spraying was carried on on 318 farms in forty-two counties on a total of 6,193 acres with an average increase of 74.7 bushels per acre obtained.

In 1919, the project as previously outlined was performed in two places. At State College, the average of the plots sprayed six times with Bordeaux and insecticide was 152.6 bu. per acre; those sprayed with insecticide only 122.5 bu. per acre, a gain of 30 bu. per acre. Early blight was unusually severe, tipburn present but not severe

until about September 1st, late blight became epidemic and destroyed about 50 per cent of the plants in unsprayed plots. Later applications of Bordeaux more valuable than earlier because of occurrence of late blight. At State College, another field was sprayed four times when it was thought to be advantageous to the plants, on July 18th and August 5th, and 27th and September 9th. Late blight also serious on unsprayed plants. The sprayed plots yielded 309 bu. per acre; the unsprayed 229, or 80 bushels per acre increase from spraying. Heath's Late Beauty variety was used in both cases. At Girard, the experiment was also performed in 1919, using the Petoskey variety. Late blight practically absent. Average yield of plots sprayed seven times, 123.3 bushels; of those receiving only insecticide, 100.5 bu. per acre. Low yields because of badly sprouted seed. The middle to late season sprayings were found to be better when late blight was absent than late season spraying only.

Five applications of 4-4-50 Bordeaux, using pressure of 200 pounds and 100 or 125 gallons per acre, using two or three nozzles per row, gives protection against late blight in Pennsylvania and remarkable increases in yield whether late blight is present or absent.

*Delaware.*—T. F. Manns reports late blight not often serious. In 1912, 1913, and 1914, not reported; 1915, 1 per cent in northern part; 1916, little damage; 1917, 2 per cent of late potatoes affected; 1918, ½ of 1 per cent; 1919, 2 to 5 per cent of late potatoes affected. In 1920, late blight very severe; average of 10 to 20 per cent rot. F. D. Chester reported (5th Ann. Rep., 1892) co-operative spraying. In one case, yield was 96 pounds per row where sprayed 4 times; 92 pounds where unsprayed. Some blight present. Another plot yielded 101 pounds per row where sprayed 4 times; 84 pounds where unsprayed. No other data available.

*Maryland.*—J. B. S. Norton reported in 1906 (Bull. 108) that 3 years' tests showed an average increase in yield of 52 per cent from spraying 3 or 4 times from June to September.

*Virginia.*—Director T. C. Johnson and L. B. Smith of the Truck Experiment Station report that late blight rarely does any damage in eastern Virginia; but early blight and tipburn are common. Late blight occasional in western Virginia. Results of work show that profit was obtained by using Bordeaux as a carrier for arsenicals. (Bulls. 14, 17, 28). Bulletin 29, and Potato Magazine, Aug. 1919, report results showing that nicotine sulphate, fish-oil soap, and water kill more aphids than Bordeaux, arsenate and nicotine; but the latter combination gave an average of more than 25 bu. per acre increase in yield over the former. Bordeaux and arsenate gave about the same yield as the nicotine and soap, although Bordeaux does not affect aphids particularly. L. B. Smith reports Bordeaux effective for early blight in 1920.

*West Virginia.*—N. J. Giddings has published (Ann. Rep., **1909–10** Bull. 165) results of spraying tests. The results of spraying on a commercial scale, in years when very little early or late blight appeared, are as follows:

TABLE 3.

*Results of Spraying Potatoes in West Virginia*

| YEARS | LOCATION OF PLOTS | AV. YIELD, SPR. PLOTS | AV. YIELD, UNSPR. PLOTS | INC. FROM SPR. BU. | PER CENT |
|---|---|---|---|---|---|
| 1909, '12, '13 | Morgantown | 87.2 bu. | 70.5 bu. | 16.7 | 23.7 |
| 1911, 1912 | Moundsville | 78.1 " | 69.4 " | 8.7 | 12.6 |
| 1910 | Reedsville | 82.3 " | 59.1 " | 23.2 | 39.3 |

Lime sulphur reduced yields. In 1919, Professor Giddings sprayed Carman No. 3 with 5-5-50 Bordeaux, at an altitude of over 3,000 feet, using one acre spray plots and

one-half acre check plots, and obtained a 50 per cent increase in yield. Favorable results from spraying were secured also in 1920.

*North Carolina.*—R. W. Leiby has tested poisoned Bordeaux and Bordeaux without poison, with hand-picking the beetles, and with no spraying whatever. (Ext. Circs. 48, 103; Bull. N. C. Dept. Agr. 254). For the late crop in western N. C., an average for 6 years gave an increase of 52 bu. per acre from poisoned Bordeaux over check without Bordeaux or poison. Four similar tests in eastern N. C. gave an increase of 26 bu. per acre. Five years' results gave an average increase of 16.6 bu. per acre from poisoned Bordeaux as contrasted with Bordeaux alone.

*South Carolina.*—Director H. W. Barre reports late blight quite prevalent in Charleston and Beaufort Counties in 1920. Some spraying tests, but no figures as to effect on yield. Late blight seldom occurs.

*Georgia.*—H. P. Stuckey and B. B. Higgins (Bull. 123) reported for 1915 an average yield of 66 bu. per acre where sprayed twice with 4-5-50 Bordeaux mixture, and an average of 49.5 bu. per acre without Bordeaux. Increase in yield also reported in 1916. Late blight absent; but early blight common on unsprayed plots. No other data at present from Georgia.

*Florida.*—C. D. Sherbakoff reports late blight in 1912, 1917, 1918, and 1919. In 1919, the blight caused a loss of 50 per cent in the Hastings district. Cooperative experiment in 1919 with grower, leaving 3 distributed strips unsprayed, each 4 rows wide and 200 feet long, in each of two test fields of 20 acres. Results as follows:

Field 1. 20 acres new ground, sprayed 5 times beginning when plants were 8–10 inches high. Field planted on January 25th and 26th, 1919.

Field 2. 20 acre tiled field, planted on Feb. 7th and 8th, 1919, sprayed 7 times begining when plants were 5–6 inches high. Average yields were as follows:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sprayed | rows, | field | 1, 160.3 | lbs. | No. | 1 | potatoes; | total | 225.7 lbs. |
| Unspr'd | " | " | 1, 115.3 | " | " | 1 | " | " | 184.7 " |
| Sprayed | " | " | 2, 258.3 | " | " | 1 | " | " | 327.7 " |
| Unspr'd | " | " | 2, 170.3 | " | " | 1 | " | " | 243.3 " |

The above figures are for 2 rows, and are the average of the 3 counts in each case. Average increase in yield where sprayed, 29 per cent, and 45 per cent increase in No. 1 potatoes. Average yield of field No. 1, 31 barrels per acre; field No. 2, 43 barrels per acre. Cost of spraying the 40 acres, about $286; increased yield worth $2,210. Further data in Florida Grower 20, No. 1, 1919. Probably would pay to spray each year in Florida; though results when late blight is absent not yet determined.

*Ohio.*—A. D. Selby reports potato spraying not commonly practised, because Ohio has late blight less than 40 per cent of the seasons. Spraying pays when late blight occurs. Value to growers of applying Bordeaux each year not definitely known.

*Indiana.*—H. S. Jackson reports late blight rare or absent; early blight not serious; tipburn serious. F. C. Gaylord wrote in 1918 that very few growers used Bordeaux; but those who did considered that it paid. No results of experimental tests available

*Illinois.*—G. P. Clinton reported (Bull. 40, 1895) some increase from spraying potatoes with Bordeaux and poison. J. Pieper writes that farmers who have made comparisons feel that there is considerable advantage in the use of Bordeaux. No definite figures.

*Michigan.*—G. H. Coons writes that Michigan potato spraying must give protection against early blight, hopper burn and late blight. Of these early blight is probably least important, and hopper burn, because it is present nearly every year, is probably the greatest loss producer, Late blight so far as available records show has been

present in epidemic form in 1885, 1896, 1900, 1902, 1903, 1905, 1912, 1915, 1920. Since 1911, it can definitely be stated that hopper-burn has reduced the potato crop 25 per cent in the case of late potatoes and 50 per cent in the case of early potatoes, working along with drought to depress the average yield per acre for the state in some seasons as low as 60 bushels.

A questionnaire to leading potato dealers, county agents, and potato growers showed that potato spraying was not at all generally practiced, some of the counties growing large acreages of potatoes reporting that spraying for diseases was not practiced at all.

Evidence as to value of spraying is not available for any consecutive period. The college has carried on many demonstrations since 1890; but results of these are not available. C. A. McCue (Bull. 236) obtained in 1905, a year when late blight was a factor, increases of 28 to 40 bu. per acre from 4-4-40 Bordeaux applied 4 to 14 times, and an increase of 11.5 bu. per acre from lime alone applied 14 times. He also reported large increases in yield from certain farmers' trials.

In 1912, H. I. Eustace (Circ. 15) published the results of spraying tests made in several preceding seasons, reporting that spraying paid during the absence of blight. In 1911, an increase of 39 bu. per acre was obtained from 4 applications of Bordeaux.

For twenty years, Hon. Jason Woodman, a progressive farmer in southwestern Michigan, has sprayed potatoes as part of the farm practice. These tests with land well adapted to potatoes and heavily fertilized have given the best results yet obtained in influencing yields. Mr. Woodman reports an average gain of the sprayed over the check every year with one exception, and in this year, the spraying was done with commercial Bordeaux. The average gain from spraying for the period is put between 75 and 100 bu. per acre.

FIG. 1. A CONSPICUOUS EXAMPLE OF THE EFFECT OF BORDEAUX, CENTER TWO ROWS UNSPRAYED. Photographed in 1915 near Kalamazoo, Mich., by C. W. Ward. By courtesy of G. H. Coons.

In 1915, spraying tests by farmers near Kalamazoo, Michigan, gave increases in yield of 130 to 166 bu. per acre from 5 sprayings.

G. H. Coons (Spec. Bull. 85, 1918) advises spraying every year for those growing potatoes intensively, and everyone should spray, if July is cold and wet.

*Wisconsin*.—Spraying often necessary because of late blight. J. G. Milward and R. E. Vaughan report favorable results from spraying even in the absence of late blight. from increased foliage growth and protection against flea-beetle and leaf hopper damage. Potato spraying on increase among progressive growers, and better machines are being introduced. R. D. Rands (Wis. Res. Bull. 42, 1917) reported an average of slightly over 10 per cent increase in yield for early varieties, and from 10 to 43 per cent increase in yield for late varieties from the use of Bordeaux in the absence of late blight. Early blight was profitably controlled by spraying.

*Minnesota*.—Late blight not uncommon; early blight and tipburn (principally hopper burn) common. G. R. Bisby and A. G. Tolaas have summarized (Bull. 192) the results. The average increase for 14 years at St. Paul was over 31 bu. per acre for late varieties, and about 27 bu. per acre for early varieties. Experiments elsewhere in the state also demonstrate that the application of 5-5-50 Bordeaux pays even in the absence of late blight. Weaker Bordeaux found less valuable. Some indication of better yield succeeding year from tubers produced under sprayed vines.

*Iowa*.—Late blight not common. A. T. Erwin, bulletin 171, 1917, reported five years' result of spraying against tipburn and early blight. Marketable potatoes yield as follows, average 5 years: 3 applications 5-5-50 Bordeaux, 114.3 bu. per acre; 5 applications, 120.9 bu.; 7 applications, 121.5 bu.; check, 103.9 bu. Cost figured at $0.96 per application per acre. Five applications most profitable. The Departments of Entomology and Plant Pathology cooperated in 1920 in experiments with Bordeaux 4-4-50 plus black leaf 40, one pint per 100 gallons of mixture, and report fair control of tipburn. In one field, average 0.14 nymphs of leaf hopper per leaf where sprayed, and 0.50 where unsprayed. Many nymphs killed.

*Missouri*.—J. T. Rosa, Jr., reports that spraying has not been practiced by growers for the control of diseases. No data as to the effect on yield. Early blight not ordinarily serious, tipburn the main limiting factor in growing potatoes in this section during the summer season. Late blight practically absent.

*Manitoba, Saskatchewan. Alberta*.—Late blight absent because of dry atmosphere, early blight and tipburn uncommon. Experiments with Bordeaux not yet tried. In areas in Manitoba and Saskatchewan, and around Edmonton, Alberta, the Colorado beetle is rare or absent, so that even insect sprays are not applied. Flea beetle quite common, aphids often abundant late in the season, leaf hoppers not serious.

*North Dakota*.—No late blight. Early blight and tipburn not serious. H. O. Werner found (Bull. 129) increased yield to result from Bordeaux.

*South Dakota*.—Late blight rare, early blight and tipburn common. Manley Champlin reported Bordeaux mixture little used. Materials are difficult to obtain throughout the state. In 1918, tests at Brookings gave yield of 96.7 bu. per acre sprayed with Bordeaux, and 78.3 bu. per acre without Bordeaux for Early Ohios, and 67.5 and 84.2 bu. per acre respectively for "Bugless." Reasons for inconsistent yields uncertain. No other data available.

*Nebraska*.—G. L. Peltier reports no data as to the results of spraying. Early blight and tipburn present.

*Kansas*.—L. E. Melchers performed spraying experiments during 1918, 1919, and 1920. The results are important, for, in Kansas, late blight does not occur; but early blight, tipburn, and hot weather cut down the yield. Melchers' figures cannot be given in full here. In 1918, a half acre plot planted to northern grown seed was sprayed by H. H. Haymaker with 2-3-50, 3-4-50, and 4-5-50 Bordeaux plus lead arsenate, four or three applications. Average yields per row were as follows:

| | 2-3-50 | 3-4-50 | 4-5-50 |
|---|---|---|---|
| Irish Cobbler | 28.75 lbs. | 31.42 lbs. | 30.17 lbs. |
| Corresponding check | 27.12 " | 31.75 " | 38.00 " |
| Early Ohio | 31.42 " | 35.42 " | 39.25 " |
| Corresponding check | 30.37 " | 37.75 " | 35.25 " |

In 1919, a similar experiment was performed. The results from various strengths of Bordeaux and various schedules are as follows:

| Variety | Treatment | Av. yield per row | Inc. in yield per row | |
|---|---|---|---|---|
| | | | lbs. | per cent. |
| Irish Cobbler | checks | 85.00 | | |
| Irish Cobbler | sprayed | 89.25 | 4.25 | 5.00 |
| Early Ohio | checks | 69.66 | | |
| Early Ohio | sprayed | 72.50 | 2.84 | 4.00 |

The 4-5-50 Bordeaux gave the best results, the 3-4-50 next best, and the 2-3-50 the poorest results.

In 1920, the experiment was carried on in a ten acre field of the best known grower in the Kaw Valley. Early blight and tipburn almost absent, a rare condition in Kansas. The average yield of sprayed Early Ohios was 281.4 bu. per acre; unsprayed, 280.9; of Irish Cobbler: sprayed, 282.0; unsprayed, 303.0.

Under Kansas conditions, the three seasons' evidence indicates that Bordeaux mixture exerts little influence on the yield.

*Kentucky.*—W. D. Valleau reports tests at Lexington in 1920 with two sprayings in the spring, which resulted in about ⅙ increase in yield. Late blight rare; early blight slight; tipburn common.

*Tennessee.*—S. M. Bain published bulletins (Vol. 8[1], Vol. 15[2]) dealing with fungicides, but no data as to the effect of Bordeaux on potatoes.

*Alabama.*—G. L. Peltier reports that potato spraying experiments have not been performed. Early blight and tipburn often present.

*Mississippi.*—D. C. Neal reports that late blight has not been found. Early blight common and spraying would probably pay, but no data available.

*Louisiana.*—C. W. Edgerton reports that late blight has been found, but that conditions are not suitable for its general development. Early blight and tipburn not ordinarily serious. Value of Bordeaux unknown.

*Texas.*—J. J. Taubenhaus reports late blight absent; early blight and tipburn present. Tipburn worse on plants from potatoes injured by frost in transit to Texas. Potatoes grown as an early crop. No definite figures as to the effect of spraying.

*Oklahoma.*—No experimental data found as to the effect of spraying potatoes with Bordeaux mixture.

*Arkansas.*—J. A. Elliot reports late blight rare, early blight not very serious, tipburn rather serious. Bordeaux used in 1920, but no effect on yield. Different number of applications also gave little difference.

*Montana.*—Late blight absent; early blight and tip-burn not serious. D. B. Swingle reports no data as to the effect of Bordeaux on yield.

*Wyoming.*—A. F. Vass reports no publications on this subject.

*Colorado.*—H. G. MacMillan reports tipburn and early blight slight; late blight absent. No data as to the effect of Bordeaux.

*New Mexico.*—F. C. Werkinthin wrote in 1918 that late blight does not occur, and early blight is not common. L. H. Leonian wrote in 1920 that no data had yet been obtained as to the effect of using Bordeaux.

*Arizona.*—J. G. Brown reports early blight reduced yield 30 per cent in 1919, and 5 per cent in 1920, in northern Arizona. Bordeaux has been used successfully for early blight, but no figures available.

*Utah.*—B. L. Richards states that tipburn is serious. Early and late blight do not cause damage. Value of Bordeaux unknown.

*Nevada.*—C. W. Lantz reports Nevada not troubled with diseases which make spraying necessary. No data as to effect of Bordeaux.

*Idaho.*—C. W. Hungerford reports late blight absent; early blight and tipburn not serious. Growers do not use Bordeaux. No data as to its effect on yield.

*British Columbia.*—W. Newton reported (Agr. Gaz. Can., **2**: 334, 1915) increases in yield of from 5 to 58 bu. per acre from spraying 3 and 5 times with a 4-4-40 (4-4-50 U. S. gallon) Bordeaux. This was during an unusually dry season when late blight was not very prevalent. French (Brit. Col. Circ. 10) reports that late and early blights do little damage in dry portions of British Columbia. J. W. Eastham has other data, received too late to include here.

*Washington.*—F. D. Heald reports Bordeaux used to a limited extent in the Puget Sound region where late blight occasionally occurs. Foliage troubles of potato rare in the Yakima Valley. Tests there in 1918 as follows:

No spraying, average of two tests, 255.5 lbs.
3-3-50 Bordeaux once, average two tests, 189.0 lbs.
3-3-50 Bordeaux twice, average two tests, 238.0 lbs.

No value from spraying in this experiment, where leaf diseases were absent. No other data at present available.

*Oregon.*—M. B. McKay reports early blight and tipburn slight, late blight about once in ten years west of Cascade Mountains, quite serious in 1920. No data as to effect of Bordeaux in Oregon.

*California.*—Tests began with copper-lime sprays in 1886 (See Exp. Sta. Rec. **41**: 405, 1919). J. T. Barrett reports early blight sometimes rather destructive especially to the second crop; but no data as to the value of Bordeaux on potatoes in southern California.

*U. S. Department of Agriculture.*—Much early work was done in testing and introducing Bordeaux after its discovery in France (see Lodeman, E. G., The spraying of plants, New York, 1913, for a summary of this work). L. A. Hawkins published, in 1912, a bulletin on "Some factors influencing the efficiency of Bordeaux mixture." (Bur. Pl. Ind., Bull. 265.) F. C. Cook of the Insecticide and Fungicide Laboratory has been testing lime-water and barium-water sprays (U. S. Dept. Agr., Bull. 866) and found them effective on potatoes. He also reports tests (Jour. Agr. Res. **20**: 623–636, 1921) indicating that the percentages of solids and of nitrogen is higher in tubers from sprayed vines than in tubers from unsprayed vines; but found no indication that tubers from sprayed vines produced sprouts with a composition or rate of growth different from sprouts from tubers from unsprayed vines.

## SUMMARY AND CONCLUSION

Bordeaux is necessary to control late blight in the Maritime Provinces, in Quebec, in northern New England, and in New York. Increased yields are general in the absence of late blight. Late blight, is less common in Ontario, Rhode Island, Connecticut, New Jersey, Delaware,

Pennsylvania, Ohio, Michigan, Wisconsin, Minnesota, and Florida. Careful spraying each year, nevertheless, pays in Pennsylvania, and evidently also in Ontario, Michigan, Wisconsin, and Minnesota. Spraying Cobblers in New Jersey has been found to pay; but main crop Giants may be reduced in yield from Bordeaux. In Rhode Island and Connecticut, the late crop is in general benefited from spraying. Late blight occasionally occurs in certain other eastern and central states, and Bordeaux appears valuable in Maryland, Virginia, West Virginia, North Carolina, Georgia and perhaps Kentucky, although further experiments are needed in certain of these states. Spraying is, of course, valuable in any region in years in which late blight is serious. Bordeaux has been found valuable in Iowa and under certain conditions in North Dakota and British Columbia. Bordeaux did not exert much influence in Kansas during 3 years nor in Arkansas in 1920. The value of Bordeaux is uncertain over most of the rest of North America.

Copper dust appears valuable, as indicated by the Canada and New York reports. Burgundy mixture was found scarcely equal to Bordeaux in Canada. Work on the resistance of potato varieties to late blight has been performed in Rhode Island, Canada, and elsewhere: see Wm. Stuart, Vermont Sta. bulletins 115, 1905; 122, 1906; and 179, 1914, and L. R. Jones, U. S. Dept. Agri., Bur. Pl. Ind. Bulletin 87, 1905, and Jones, Giddings and Lutman U. S. Dept. Agr., Bur. Pl. Ind., Bulletin 245, 1912. Data on the chemical, physical, and biological effects of Bordeaux have been published by workers in New Hampshire, Vermont, U. S. Dept. Agr., Canada; see also Martin, Jour. Agr. Res. **7**: 529–548, 1916, Duggar and Bonns, Ann. Mo. Bot. Gard. **5**: 153–176 and Ritzema Bos, abstract in Bot. Abs. **3**: 235, 1920. Data from Virginia, Iowa, Maine, Wisconsin, and Canada refer to the use of various compounds with Bordeaux to kill insects.

It is evident from this summary that our knowledge of the value of Bordeaux mixture on potatoes is still very incomplete. Tests of Bordeaux and other compounds are needed in many parts of North America in order to determine their value under various conditions. There is excellent opportunity for cooperative spraying work with entomologists. The best fungicide to apply, its effect on the potato plant, and the optimum schedule for spraying potatoes, need further study. Many workers will desire to compare spraying and dusting. Questions of scientific interest as well as practical importance await experimentation. The results obtained will naturally be published by the workers; but the writer will gladly act in any capacity he can in correlating or bringing together miscellaneous information relative to the use of Bordeaux mixture and other fungicides on potatoes.

## REPORT OF THE TWELFTH ANNUAL MEETING OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

The twelfth annual meeting of the Society was held at the Reynolds Club Theater, University of Illinois, Chicago, Illinois, December 27–31, 1920, in conjunction with the American Association for the Advancement of Science, the Botanical Society of America, and other scientific societies. President W. A. Orton presided. The headquarters of the Society were at the Fort Dearborn Hotel.

About one hundred and ten members were present, the largest attendance recorded at any of the annual meetings. Seventeen new members were elected, making the total active membership of the Society five hundred and twelve on January 1, 1921.

There were eighty papers on the regular program, abstracts of which appeared in the January number of PHYTOPATHOLOGY. Copies of the abstracts were distributed to all members of the Society in advance of the annual meeting and the new plan of conducting the sessions adopted last year at St. Louis was followed. The papers were not formally read, but the entire time of the sessions was devoted to informal discussion, the basis of the discussion being the published abstracts. Portions of two sessions were devoted to consideration of the diseases of potatoes and of beans.

There were three joint sessions with other societies. On Wednesday afternoon, December 29, occurred the annual meeting of Section G of the American Association for the Advancement of Science. At this meeting Dr. L. H. Pammel gave an address as Vice President of Section G on Some Phases of Economic Botany, and papers were presented by Dr. C. R. Ball, Dr. H. C. Cowles and Dr. F. L. Stevens in a symposium on the Relation of Botany to Human Welfare. On Thursday afternoon, December 30, the American Phytopathological Society joined in an invitation program with the Botanical Society of America and the American Society of Economic Entomologists. Papers were presented by Prof. C. V. Piper on Plants and Plant Culture, by Dr. E. C. Stakman on Recent Investigations on the Black Stem Rust of Wheat and Other Cereals, and by Dr. H. S. Shantz on Natural Vegetation and Agriculture in Africa. On Friday morning, December 31, a joint session was held with the American Association of Economic Entomologists, which was devoted to a discussion of dusting as a means of controlling injurious insects and plant diseases. Insect control by dusting was discussed by Dr. P. J. Parrott, Dr. T. J. Headlee, and Dr. A. L. Quaintance. Plant disease control was discussed by Dr. N. J. Giddings and Dr. H. A. Edson. These five papers, with a full report of the discussion which followed their presentation, will appear in the April number of the Journal of Economic Entomology, where they will be accessible to pathologists interested in the subject of dusting.

The annual dinner of the Society was held Thursday evening, December 30, at the Stevens Restaurant, and was attended by one hundred and twenty-five pathologists and botanists. After the dinner the stern visages of the assembled pathologists relaxed in kindly and tolerant appreciation of several toasts, and the "phytopathological anthem" was rendered by a quintet previously unknown to fame.

The following officers were elected:

*President*, Dr. Donald Reddick, Cornell University, Ithaca, New York.

*Vice-President*, Dr. G. H. Coons, Michigan Agricultural College, East Lansing, Michigan.

*Councilor for two years*, Dr. N. J. Giddings, West Virginia University, Morgantown, West Virginia.

*Councilors for one year:* (chosen by the divisions of the Society) Dr. J. H. Faull, University of Toronto, Canada, representing the Canadian division; Dr. H. S. Reed, Citrus Experiment Station, Riverside, California, representing the Pacific Coast division; and Dr. H. R. Rosen, University of Arkansas, Fayetteville, Arkansas, representing the Southern division.

*Representative on the Board of Control of Botanical Abstracts,* Dr. L. R. Jones, University of Wisconsin, Madison, Wisconsin.

*Members of the editorial board of Phytopathology* (chosen by the Council of the Society): Editor in Chief, Dr. Perley Spaulding, United States Department of Agriculture, Washington, D. C., associate editors for three years, Prof. J. Franklin Collins, Brown University, Providence, Rhode Island; Dr. L. R. Hesler, University of Tennessee, Knoxville, Tennessee; Dr. A. G. Johnson, University of Wisconsin, Madison, Wisconsin; associate editor for two years to fill vacancy, Prof. J. A. Stevenson, United States Department of Agriculture, Washington, D. C.; business manager for one year, Dr. G. R. Lyman, United States Department of Agriculture, Washington, D. C.; advertising manager for one year, Prof. Roy G. Pierce, United States Department of Agriculture, Washington, D. C.

The Society voted to hold its next annual meeting at Toronto, Canada, December 26–31, 1921, in conjunction with the American Association for the Advancement of Science.

REPORT OF THE TREASURER, 1920

| | | |
|---|---|---|
| *Receipts:* | | |
| Balance from 1919 | $1,070.60 | |
| Membership dues | 2,546.70 | |
| Excess dues | 28.00 | |
| Exchange | 7.50 | |
| Subscription for exch. with International Inst. Agr. | 5.50 | |
| Copying list of members for A. Thomas | 5.00 | |
| Interest | 31.78 | $3,695.08 |
| *Expenditures:* | | |
| Member subscriptions | 1,244.00 | |
| Excess dues returned | 28.00 | |
| Discount Canadian checks | 1.33 | |
| Checks returned by bank | 4.00 | |
| Annual appropriation to PHYTOPATHOLOGY | 200.00 | |
| Clerical assistance | 71.08 | |
| Postage | 23.00 | |
| Printing | 86.00 | |
| Supplies | 3.60 | |
| Secretary's expenses, 1919 | 17.20 | |
| Stationery, including stamped envelopes | 76.65 | |
| Loans to PHYTOPATHOLOGY | 575.00 | |
| Sinking fund transferred to PHYTOPATHOLOGY | 1,000.00 | |
| Subscription for exch. with Int. Inst. Agr. | 5.50 | $3,335.36 |
| Balance | | 359.72 |
| Amount due Phytopathology account— | | |
| Sinking fund | $165.58 | |
| Member subscriptions | 29.00 | 194.58 |
| Actual balance | | 165.14 |

During 1920 the Society lost seventeen members through death, resignation, and non-payment of dues. The seventeen new members just elected exactly making up this loss. There are now eighty-six life sustaining members, and four hundred and twenty-six regular members, a total of five hundred and twelve.

*Financial Statement of the Business Manager of Phytopathology, 1920*

| | | | |
|---|---|---|---|
| *Receipts:* | | | |
| Balance from 1919 | | $ 552.12 | |
| Subscriptions and sales | | 1,370.34 | |
| Publishing in PHYTOPATHOLOGY | | 527.60 | |
| Annual appropriation from Am. Phyto. Soc | | 200.00 | |
| Advertising in 1919 | | 221.45 | |
| Member subscriptions | | 1,244.00 | |
| Interest | | 60.50 | |
| Loans | | 1,375.00 | |
| Sinking fund | | 1,500.00 | $7,051.01 |
| *Expenditures:* | | | |
| Manufacture of journal: | | | |
| No. 9, Vol. IX | $1,017.16 | | |
| No. 10, Vol. IX | 316.42 | | |
| No. 11, Vol. IX | 281.35 | | |
| No. 12, Vol. IX | 359.03 | | |
| Balance on No. 9, Vol. IX | 35.20 | | |
| No. 1, Vol. X | 595.16 | | |
| No. 2, Vol. X | 366.56 | | |
| No. 3, Vol. X | 431.36 | | |
| No. 4, Vol. X | 518.36 | | |
| No. 5, Vol. X | 265.73 | | |
| No. 6, Vol. X | 231.24 | | |
| No. 7, Vol. X | 220.40 | | |
| No. 8, Vol. X | 189.47 | | |
| No. 9, Vol. X | 239.84 | | |
| Balance on bills | 28.82 | | |
| Alterations | 16.98 | | |
| Alterations | 4.48 | | |
| Alterations | 3.68 | $5,121.24 | |
| Miscellaneous | | 195.94 | |
| Insurance | | 12.35 | |
| Mortgage, sinking fund ($1500) | | $1,470.00 | $6,799.53 |
| Balance | | | $251.48 |

An auditing committee, consisting of E. L. Nixon, J. A. McClintock, and R. E. Vaughan, was appointed to examine the accounts of the treasurer and business manager. This committee reported the accounts correct and the reports were adopted.

### PHYTOPATHOLOGY

At the close of the phytopathologists' dinner on Thursday evening the business manager reported on the future plans of PHYTOPATHOLOGY:

"In 1918 there was issued a volume of six hundred and twenty-seven pages, in 1919 five hundred and eighty-seven pages, and in 1920 five hundred and fifty-four pages. During these years printing costs have risen enormously, but the pressure of accumulated manuscript in the hands of the editor-in-chief has made it impossible to reduce the number of pages sufficiently to keep pace with rising costs. The financial statement above shows loans of $1,375 contracted to pay current bills. It is estimated that if all outstanding bills against PHYTOPATHOLOGY up to December 31, 1920, were received and paid, the accounts would show a deficit of $1,787.36.

"These financial problems have been receiving very careful consideration by the Council. The deficit shown above has been steadily increasing for the past four years and the time has come when changes and adjustments must be made which will bring expenditures below receipts and permit the gradual liquidation of present indebtedness. The following plan has been decided upon and the business manager requests the cooperation of all members of the Society in carrying it out:

"1. The cost of manufacturing PHYTOPATHOLOGY must be reduced. Inquiry has shown that printing service can be purchased of well-established firms, experienced in producing scientific journals, at rates materially less than those charged by Williams & Wilkins Company, of Baltimore, Maryland. Accordingly relations with Williams & Wilkins Company have been severed and arrangements completed with the Intelligencer Printing Company of Lancaster, Pennsylvania, to manufacture PHYTOPATHOLOGY during 1921. The Intelligencer Printing Company already issues several botanical and other scientific journals and their prices are materially below those of Williams & Wilkins Company.

"2. Other costs must be reduced. The Williams & Wilkins Company have been handling subscriptions, advertising, and the sale of back numbers on a percentage basis, and also performing various other publishing services, for all of which PHYTOPATHOLOGY has been charged. The business manager will now assume direct charge of all these matters, and the Council has authorized him to select two assistants for this work. Through the courtesy of President A. F. Woods, the back numbers of PHYTOPATHOLOGY will be stored free of charge at the University of Maryland, College Park, Maryland, and will be under the immediate supervision of Prof. C. E. Temple and Prof. R. A. Jehle.

"3. Our revenues must be increased. To this end the hearty cooperation of all members of the Society is earnestly requested in securing new members, new subscribers, and new advertisements.

"This plan places a greatly increased burden upon the business manager and his immediate helpers, but the hearty backing of the whole Society is counted on, and it is confidently expected that in this way it will be possible to pay all costs and also enable PHYTOPATHOLOGY to discharge its obligations to phytopathological science in a manner worthy of the Society."

The Society approved of the plans as stated, and immediately voted unanimously to pay off by voluntary subscriptions of the members the deficit under which PHYTOPATHOLOGY is struggling. A canvass was taken of the members present, which resulted in $576.50 in cash and pledges. Prof. H. H. Whetzel was requested to bring the facts to the attention of all members of the Society not present at the dinner in an endeavor to raise the entire amount of the deficit, and thus relieve the journal of all handicap in inaugurating the new plan of operation outlined above.

REPORT OF THE ADVISORY BOARD

The Advisory Board reported through its chairman, Dr. G. R. Lyman, on the work

of the year. The custom inaugurated in 1919 of holding a summer field meeting was successfully continued. The 1920 meeting was held August 3–6, beginning in the Shenandoah Valley at Staunton, Virginia, and extending northward through West Virginia and Maryland to Gettysburg, Pennsylvania, one day being spent in each of the four states. The meeting was devoted chiefly to apple and peach diseases. Local arrangements were in charge of the plant pathologists of the states visited, and many demonstrations and exhibits of fruit diseases were prepared, as well as special comparative spraying and dusting experiments on the control of various diseases. About seventy-five plant pathologists were in attendance, together with a number of horticulturists, entomologists, and other specialists, representing the United States Department of Agriculture and the experiment stations in the United States and Canada. In addition the federal government detailed soil specialists from the Geological Survey, the Bureau of Soils, and the Bureau of Chemistry to attend the conference and participate in the discussions and relations of soils to plant diseases. W. B. Brierly, Head of the Department of Mycology, Institute of Plant Pathology, Rothamstead Experiment Station, Harpenden, England; Etienne Foëx, Directeur de la Station de Pathologie vegetale, Paris, France; G. Rossati, Royal Agrarian Delegate to the Italian Chamber of Commerce, New York City, and K. Nakata, Professor of Plant Pathology, Agricultural Department, Kiushiu Imperial University, Fukuoka, Japan, were present as the official representatives of England, France, Italy and Japan, respectively. A report on this meeting was published in the November number of PHYTOPATHOLOGY, pages 496–498.

Plans for the 1921 field meeting are already well advanced. The 1921 meeting will be devoted to cereal diseases and will be held July 19–22 in the vicinity of St. Paul, Minnesota, and Fargo, North Dakota. The following committee on arrangements has been appointed: E. M. Freeman, chairman, and H. L. Bolley, H. B. Humphrey and L. E. Melchers. It is expected that a number of foreign cereal pathologists will be present.

The Advisory Board has continued its service as the Committee on Phytopathology of the Division of Biology and Agriculture of the National Research Council. The most important matter considered in this connection during the year was the organization of the Crop Protection Institute, concerning which the members of the Society have already been informed. The Crop Protection Institute is the outcome of the spontaneous desire on the part of plant pathologists, economic entomologists, and certain business men to secure united attack on certain common problems. While this type of organization is in many respects an experiment, the association of these groups holds large possibilities of important service to agricultural science. The Institute has been organized under the auspices of the Division of Biology and Agriculture of the National Research Council.

Data for the 1920 list of active phytopathological projects are now being collected and it is hoped the list may be issued soon. The preparation of the 1920 list has been delayed by slowness on the part of pathologists in supplying information. There must be a more hearty response in the future if the preparation of this list is to be continued as an annual affair.

Some progress has been made during the year on certain cooperative projects. Prof. G. R. Bisby will shortly publish in PHYTOPATHOLOGY a report of progress on the potato spraying project, of which he is the leader. Dr. I. E. Melhus reports definite progress on the potato seed treatment project. During 1920 a cooperative project on dusting as a means of controlling plant diseases of orchard crops was inaugurated under the leadership of Dr. N. J. Giddings. Much interest has been manifested in this project and experiments were carried out during 1920 in a number of states.

### THE PHYTOPATHOLOGICAL INSTITUTE

Dr. E. M. Freeman reported as chairman of the committee on the Phytopathological Institute. While the Institute has not been secured and funds are not yet in sight, there is cause for encouragement. Definite progress has been made in developing the fundamental idea of the Institute and in impressing influential persons with the need for such an institution. There is every reason to believe that a phytopathological institute will be established before many years.

### RESOLUTIONS

On motion a committee on resolutions, consisting of E. A. Bessey, F. D. Kern, and J. H. Faull, was appointed by the president. This committee reported the following resolutions, all of which were unanimously adopted:

1. On the death of F. Kölpin Ravn.

The science of botany in general and of phytopathology in particular has suffered an almost irreparable loss in the sudden death of Denmark's great phytopathologist, Dr. F. Kölpin Ravn. His fame and usefulness far transcended the political boundaries of his native land. His several visits to America have always been a source of great inspiration and help to American investigators, with whom, on his part, he felt the greatest friendship. Dying suddenly in the course of a visit to this country, it is particularly fitting that the American phytopathologists express their sympathy and regret.

*Therefore, Be It Resolved,* That the American Phytopathological Society express by a rising vote our sense of the great loss suffered by science in the death of Dr. F. Kölpin Ravn, and furthermore the great personal loss felt by those who had learned to known and love his kindly helpful nature, and further:

*Be It Resolved,* That the secretary of this Society be instructed to transmit our expression of sympathy to the family of Dr. Ravn, to his colleagues at the Landbohojskölen, and to the Danish Government, and to spread these resolutions upon the minutes of the Society.

2. On the death of S. M. McMurran.

*Whereas;* The death of Mr. S. M. McMurran, pathologist in the Office of Fruit Disease Investigations of the Bureau of Plant Industry, United States Department of Agriculture, has robbed this country of an investigator of great ability and promise and a man of great personal worth;

*Therefore, Be It Resolved,* That this Society express by a rising vote its regret at Mr. McMurran's untimely death, and direct the secretary to transmit to his family the expression of our sympathy and to spread these resolutions upon the minutes of the Society.

3. On the publication of Farlow's Bibliographical Index.

*Whereas;* The development and progress of all studies on the various organisms which cause plant diseases are dependent upon an intimate knowledge of mycological literature; and,

*Whereas;* Farlow's Bibliographical Index of North American Fungi is an exhaustive compilation of mycological literature with valuable notes by Dr. Farlow; and,

*Whereas;* The first volume of the Index, which was published in 1905 by the Carnegie Institution of Washington, has proved to be invaluable to workers in the fields of plane pathology and mycology, both as a time saver, and as a guide to many workers; and,

*Whereas;* Dr. Farlow's death has brought his work upon the Index to a close;

*Therefore, Be It Resolved,* That the Carnegie Institution of Washington be respect-

fully urged to givr earnest consideration to the question of resuming publication of the Index in the near future.

4. On the work of Dr. Arthur.

*Whereas;* During his long and active life Doctor J. C. Arthur has accumulated a wealth of material upon the subject of rusts which is of immense value to science, and whereas it is highly desirable that following the completion of the treatise on rusts in the North American Flora Doctor Arthur should continue his writing and that all needed facilities and assistance should be furnished him.

*Therefore, Be It Resolved,* That the American Phytopathological Society approve the movement now under way to secure such facilities and request the Advisory Board to bring this subject to the attention of the National Research Council.

5. Of appreciation for courtesies shown.

*Whereas;* The University of Chicago has received the visiting scientists with a most cordial hospitality, and

*Whereas;* The local committee on arrangements has most successfully provided not only for the proper conduct of the meetings, but also for the comfort and entertainment of the visitors,

*Therefore, Be It Resolved,* That the American Phytopathological Society direct its secretary to express to President Judson its appreciation of the hospitality shown by the University, and to the chairmen of the local committees on arrangements its gratitude for, and recognition of the courtesies shown; and, further, to spread this resolution upon the minutes of the Society.

### CROP PROTECTION INSTITUTE

The Council considered the organization and objects of the Crop Protection Institute and the responsibilities the Society was asked to assume in relation to it, and after discussion requested the Advisory Board to formulate a plan under which the American Phytopathological Society will be willing to participate in the work of the Institute. The following resolution was formulated by the Advisory Board and was recommended to the Society for adoption:

*Resolved,* That the American Phytopathological Society participate in the work of the Crop Protection Institute, with the stipulation that the connection of the scientific organizations with the Crop Protection Institute shall not be used for advertising purposes by the participating commercial concerns.

The Society voted to adopt the resolution and asked the Advisory Board to select three trustees to represent the Society on the Board of Control of the Institute. The Advisory Board selected F. D. Fromme, of Virginia Polytechnic Institute, for a term of three years; C. R. Orton, of the Pennsylvania State College, for two years; and G. H. Coons, of Michigan Agricultural College, for one year.

### MISCELLANEOUS BUSINESS

The secretary's report of the eleventh annual meeting, held at St. Louis, as published in No. 4, Volume X of PHYTOPATHOLOGY, was adopted without correction.

On recommendation of the Council, the Society voted to appropriate from its available funds the sum of five hundred and seventy-five dollars for the use of Phytopathology during 1921; also that beginning with 1921 the treasurer be authorized to transfer three dollars of the annual membership dues, instead of two dollars as in the past, to the use of PHYTOPATHOLOGY. The Society also requested the Council to consider the desirability and feasibility of increasing the subscription price of PHYTOPATHOLOGY.

It was voted unanimously that a committee be appointed by the president of the Society to take the necessary steps to secure the establishment of an F. Kölpin Ravn fellowship in Phytopathology for the use of Scandinavian students. President Orton appointed L. R. Jones, Donald Reddick and A. G. Johnson. This committee was authorized to enlarge its numbers as might be found expedient.

ACTION OF THE COUNCIL

The Council reported the following action for the information of members of the Society:

*The Divisions of the American Phytopathological Society.* It was noted that the term of service of the three members of the Council chosen annually by the three Divisions shall begin at the close of the annual meeting of the Society next following their election by the Divisions and shall terminate with the close of the annual meeting one year later.

The Council voted that in the future, proceedings of the Division meetings, abstracts of papers presented, etc., shall be printed in PHYTOPATHOLOGY under the same rules which govern publication of similar matters relating to the general Society.

*Phytopathology.* It was voted to discontinue the publication in PHYTOPATHOLOGY of the lists of literature on plant diseases. This action was taken in accordance with the decision reached two years ago that the literature list would be discontinued as soon as Botanical Abstracts was in a position to list all literature. The omission of the list will permit the publication of seventy-five or more additional pages of regular text during the year.

The Council discussed the advisability of issuing an index to the first ten volumes of PHYTOPATHOLOGY. The secretary was asked to estimate the cost of such an Index and its probable sale before taking further steps.

*Advisory Board.* The Council selected G. H. Coons of Michigan Agricultural College to succeed H. S. Jackson as commissioner for the Middle West, and C. R. Orton to succeed himself as commissioner for the Northeast. The Council accepted with regret the resignation of H. W. Barre as commissioner for the South, and J. A. Elliott of the University of Arkansas was chosen to succeed him.

G. R. LYMAN
*Secretary*

## *ABSTRACTS OF PAPERS PRESENTED AT THE SECOND ANNUAL MEETING OF THE CANADIAN DIVISION, AMERICAN PHYTOPATHOLOGICAL SOCIETY, GUELPH, ONTARIO, DECEMBER 9 TO 10, 1920.*

*Studies on mosaic.* B. T. DICKSON.

Mosaic is now known in thirty genera of ten families and mosaic-like diseases in eight genera of five families. True mosaic histological symptoms are hyperplasia of palisade parenchyma in light areas, reduction of chlorophyll content in those areas and generally, increase in trichomes and glandular hairs. On the other hand, there is frequently a hypertrophy of palisade tissue in dark areas due to hyperplasia. There is definitely less carbohydrate in the light parts. Mosaic of *Vicia faba* was described. Raspberry mosaic is differentiated from "yellows." No mosaic of the Cucurbitaceae has been found in Quebec by the writer.

*Biologic forms of wheat stem rust in western Canada.* MARGARET NEWTON.

At least five biologic forms of wheat stem rust have been shown to be present in western Canada. These forms were identical with five of the strains of rust previously isolated in the United States by Stakman. A rather virulent strain was found to be quite widely distributed. It was found in eight different localities of central Saskatchewan and eastern Alberta.

*Biologic forms of wheat stem rust in western Canada.* W. P. FRASER and D. L. BAILEY.

By greenhouse experiments in 1919 four distinct forms of stem rust were found to occur in wheat in western Canada. One of these was more common and widely distributed than the others. There were indications of several other biologic forms on wheat in the same region. All of the forms separated were identical with biologic forms which were found by Dr. Stakman and his co-workers to occur in the United States.

*Leaf scorch or mollisiose of the strawberry.* R. E. STONE.

This is a recently recognized disease of strawberries in Ontario. The disease is widely distributed extending from Sarnia in the western part of southern Ontario to Ottawa in the eastern part. The leaves present a scorched or blotched appearance and all the leaves on the plant may be killed, the latter taking on a dried, burned appearance. Entire strawberry patches may look as though burned over. In the summer the blotches bear a fungus known as *Marssonia potentillae* (Desm.) Fischer. This conidial stage may persist over winter on green leaves and to a certain extent on the dead leaves. On the dead over-wintered leaves an ascigerous stage develops. This stage has been identified as *Mollisia earliana* (E. & E.) Sacc. Ascospores from this fungus infect the leaves of strawberry plants and produce typical leaf scorch. Ascospores planted in nutrient agar-agar develop Marssonia which produced the typical disease when sprayed on strawberry plants. The conclusion was reached that *Mollisia earliana* (E. & E.) Sacc. is the perfect stage of *Marssonia potentillae* (Desm.) Fischer and the disease produced has been named according to the method of Stevens. Different varieties of strawberries are not equally susceptible to the disease. The order among those observed

seems to be; Clyde, Glen Mary, Senator Dunlop, Haverland, New Williams. Suggestions for control are; clean cultivation, destruction of old foliage and early spraying with Bordeaux mixture.

*Experiments with Haskell's method or the so-called dry formaldehyde treatment for the prevention of oat smut.* J. E. HOWITT.

This method has been tested for three successive years by the Department of Botany at the Ontario Agricultural College. In all, twenty-eight field trials under ordinary farm conditions have been made and 1677 bushels of oats treated by this method. The results have been uniformly satisfactory. No injury to the grain has resulted and the control of the smut has been almost perfect. In no case has there been more than a trace of smut in any field sown with treated seed, while the amount of smut in the field sown with untreated seed for check, averaged 5.8 per cent. The advantages of this method over those which have been practiced here are simplicity, rapidity and ease of application. In our experiments it was found that one hundred bushels of oats could be treated in fifty minutes by this method; that there was no waiting for the seed to dry after treatment; no danger of it sprouting or moulding or of the grain being swollen so that it would not run freely through the seed drill.

*Upon the chemotactic attraction of fungi for slugs.* A. H. R. BULLER

Published elsewhere.

*The sound made by fungus guns and a simple method for rendering audible the puffing of Discomycetes.* A. H. R. BULLLER.

Published elsewhere.

*Development of the Geoglossaceae.* G. H. DUFF.

Published elsewhere.

*Studies in Fomes fomentarius.* J. F. FAULL.

Published elsewhere.

*Practical hints for the young plant pathologist.* L. CAESAR.

The hints in this paper are intended almost exclusively for young pathologists who are working on diseases of orchard trees, bush fruits and vegetables and who are thrown largely upon their own resources.

A good academic training is essential as a foundation but such a training will not in itself make a man a successful pathologist. The following are just as important factors in success:

1. To have the right view point or ideal in one's work; namely, to help the growers by lessening the losses caused by plant diseases.

2. To secure as early as possible from actual experience a good working knowledge of the best methods of control known today for all the more important diseases in one's particular field of work, so that the pathologist may be a valuable advisor and guide to the grower as soon as possible.

3. To select for investigation, for several years at least, only such problems as are pressing and whose solution will be of much value to those for whom he is working. All side issues should be avoided and also, for the present, all problems that have baffled the most expert pathologists of the past.

4. To study diseases as far as possible in the field or orchard under their natural conditions or surroundings, laboratory study being supplementary or subsidiary to field study. Field study has not, as a rule, received its proper share of attention in the past.

5. To make very careful and accurate notes on everything that has even the least bearing upon the problem in hand.

6. To work in cooperation with the Entomologist or otherwise to secure a working knowledge of insects and insect control; because the application of insecticides and fungicides must often be combined.

7. To be tactful and honest, avoiding bluff as a most dangerous thing.

8. To be sure of one's facts, avoiding hasty conclusions.

9. To be an enthusiast and to persevere in face of difficulties.

*Upon the ocellus function of the subsporangial swelling of Pilobolus.* A. H. R. BULLER. Published elsewhere.

# THE AUK

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# USE OF COPPER SOAP DUST AS A FUNGICIDE

FRED J. PRITCHARD AND W. S. PORTE

## INTRODUCTION

Copper soap dust, a new fungicide made from copper sulphate and either resin fish-oil soap or caustic potash fish-oil soap, has in experiments conducted for two years at the Arlington experimental farm, Rosslyn, Va., given as good control of tomato leaf spot (*Septoria lycopersici*) as either 4-4-50 liquid Bordeaux mixture or Sanders' Bordeaux dust.

As copper soap dust seems to possess very desirable properties for the control of nearly all foliage diseases the results of its effect on the control of tomato leaf spot, although limited to two seasons' use, and its method of preparation are described for the benefit of those engaged in dusting and spraying experiments on other crops.

Copper soap is similar in composition to ordinary potassium or sodium soaps used for washing purposes but contains copper instead of potassium or sodium. Like other soaps its chemical composition is determined by the composition of the oils or fats used in its preparation. As the copper soap used by the writers was made from fish-oil soaps it probably consisted of a mixture of copper stearate, copper palmitate, copper oleate, and other similar copper salts of fatty acids.

## PREPARATION OF MATERIAL

This new fungicide was made from concentrated, rather than dilute, solutions of copper sulphate and soap, because of the greater convenience and economy in handling the precipitate. A hot aqueous solution of resin fish-oil soap or potash fish-oil soap solution of about the consistency of syrup was poured into a saturated solution of copper sulphate and stirred to bring all the soap into contact with the copper. The soap solution was made just thin enough to cause a chemical reaction with the copper sulphate. The precipitate formed by the concentrated so-

lutions was as thick as mush. To prevent copper sulphate and soap from being thrown out of such concentrated solutions, the mixture was kept moderately hot until the reaction was completed. The potassium sulphate formed during the chemical readjustment was left in the mixture but whether or not it is of any importance was not determined by experiment. The precipitate was dried in the air and ground to a powder which varied in fineness owing to the difficulty of grinding copper soap without the aid of special machinery.

Copper soap dusts containing crystalline copper sulphate and soap in proportions of 1-4 and 1-6, respectively, by weight were prepared from both resin fish-oil soap[1] and caustic potash fish-oil soap.[1]

Lead arsenate was used at the rate of 2 pounds to 1 pound of crystalline copper sulphate with certain portions of these dusts in 1919 and calcium arsenate at the rate of ½ pound to 1 pound of crystalline copper sulphate in 1920.

### METHOD OF DUSTING AND SPRAYING.

The dusting was done by means of a small hand duster. In 1919 a wire screen cylinder covered with cheesecloth was set over each plant during the dusting to prevent the dust from spreading to neighboring plants. In 1920 the dusts were applied during periods of still weather without the use of the screen. As plats instead of rows were used in 1920 and the two outside rows of each plat were discarded, it was possible by careful use of the hand duster to prevent the dusts from spreading to the experimental rows of neighboring plats.

The liquid sprays used for comparison with the dusts were applied by means of a compressed air sprayer.

### RESULTS OF EXPERIMENTS IN 1919

Copper soap dusts 1-4 and 1-6 and copper soap lead arsenate dusts 1-4-2 and 1-6-2 prepared from both resin fish-oil soap and potash fish-oil soap were used in the dusting experiments in 1919. Liquid copper soap sprays and Bordeaux mixture were also used for comparison. Single rows 64 feet long were used as plats. Several replications of each treatment were made in different parts of the field. As every third row was left untreated the dusted rows will be compared with both the sprayed and the untreated rows.

The dusts were applied at the rate of 13.2 pounds per acre and the liquid sprays at the rate of 100 gallons per acre at each application.

[1] These were commercial soaps. The resin fish-oil soap contained about 48 per cent resin and 16 to 20 per cent water; the caustic potash fish-oil soap, about 25 to 30 per cent water.

As the 1-4 and 1-6 dusts made from resin fish-oil soap and from potash fish-oil soap seemed to be equally effective in the control of tomato leaf-spot, the results from these two treatments will be combined in one group and the results of all rows treated with a mixture of either of these dusts and lead arsenate will be summarized in another group. Summaries of the results obtained from these groups and from the use of liquid copper soap and of liquid Bordeaux mixture are presented in table 1.

TABLE 1

*Comparison of copper soap dust, copper soap liquid, and Bordeaux mixture in the control of tomato leaf spot (Septoria lycopersici) at Arlington Experimental Farm, 1919*

| Dust or spray liquid | Period of treatment | | Increased yield from dusting or spraying | No. of applications | No. of separate treated rows | No. of separate check rows |
|---|---|---|---|---|---|---|
| | Early | Late | | | | |
| Copper soap dust.... | ...... | 7/25–9/19 | 16.7% | 3 | 8 | 16 |
| Copper soap dust and lead arsenate.. | ...... | 7/25–9/19 | 31.1% | 3 | 6 | 12 |
| Bordeaux mixture 4-4-50........... | ...... | 7/25–9/18 | 11.3% | 4 | 2 | 4 |
| Copper soap liquid*.. | ...... | 7/25–9/18 | 12.8% | 4 | 6 | 12 |
| Copper soap liquid and lead arsenate.. | ...... | 7/25–9/18 | 36.5% | 4 | 6 | 12 |
| Bordeaux mixture.... | 6/21–9/4 | | –5.4% | 5 | 2 | 4 |
| Copper soap dust.... | 6/20–9/5 | | 1.1% | 4 | 8 | 16 |
| Copper soap dust and lead arsenate.. | 6/20–9/5 | | 15.7% | 4 | 7 | 14 |
| Copper soap liquid.. | 6/25–9/5 | | –8.6% | 5 | 6 | 12 |
| Copper soap liquid and lead arsenate.. | 6/25–9/5 | | –4.9% | 5 | 6 | 12 |

Late dusting with copper soap dust gave fully as large increases in yield of fruit as late spraying with either liquid Bordeaux mixture or liquid copper soap. The increases would probably have been greater if leaf spot had appeared earlier.

Although the rows receiving the last treatment on September 5, received a larger number of applications of fungicide than those treated until September 19, they produced less fruit, as leaf spot appeared late

* The copper soap sprays contained ½ pound of copper sulphate and 3 pounds of resin fish-oil soap in 50 gallons of liquid or one-eighth as much copper as the 4-4-50 Bordeaux mixture. Full directions for preparing copper soap liquid may be obtained from Phytopathology **9**: 554–564. 1919.

and developed chiefly in the latter part of the growing season when they were not so well protected from its attack.

The apparent reductions in yield obtained from early spraying with Bordeaux mixture and with liquid copper soap may be due either to variations in soil fertility of the sprayed and check plats or to injury from the fungicides. Similar results from early spraying have been observed in other experiments.

The large increases in yield of fruit from the use of a combination of lead arsenate and the fungicides over the fungicides alone are difficult to explain. They may have been due to insect control but no insect infestation was apparent. Moreover, similar benefits from the addition of lead arsenate to copper soap liquids were obtained in control of tomato leaf spot on the foliage in former greenhouse experiments although no benefits were obtained from lead arsenate alone.

## RESULTS OF EXPERIMENTS IN 1920.

In the dusting experiments in 1920 copper soap calcium arsenate dust of the 1-6-½ formula and Sander's Bordeaux dust of the 15-8-77 formula, i. e., 15 pounds of dehydrated copper sulphate, 8 pounds of calcium arsenate, and 77 pounds of dehydrated lime, were used at the rate of 22½ and 30 pounds per acre, respectively, at each application. Bordeaux mixture of the 4-4-50 formula was also used at the rate of 100 gallons per acre for comparative purposes.

Four parallel 5-row plats of tomatoes 230 feet long were used in these experiments, one for each of the dusts, one for the Bordeaux mixture, and one for control purposes. The control or check plat lay between the Sanders' Bordeaux and copper soap calcium arsenate plats. Data from each plat were taken only from the three central rows.

Five applications of the fungicides were made between August 3 and September 15. But little if any effect on yield of fruit was expected, as the crop was nearly grown when the experiment was started. The treatments were continued to September 15 to observe their effect on the preservation of the foliage.

Tomato leaf spot (*Septoria lycopersici*) and tomato leaf mold (*Cladosporium fulvum*) were both doing considerable damage when the spraying was begun. Although leaf spot was checked by the fungicides, leaf mold continued to cause considerable defoliation. The Cladosporium spores lying on the lower leaf surfaces beyond the effective reach of the chemicals germinated through aid of unusually moist weather and infected the newly developed foliage before it was covered with fungicides.

The increased yields from the treatments, though of little importance, for reasons already stated are expressed in percentages as follows: San-

ders' Bordeaux dust—13.7, copper soap calcium arsenate dust 1. 5 and liquid Brodeaux mixture 5.4, It would seem from these results that Sanders' Bordeaux dust caused some injury, though an allowance of the greater part of this decrease would have to be made for experimental error. The small increases from the copper soap calcium arsenate and Bordeaux plats are also doubtfully significant, as they do not exceed average differences due to variations in soil fertility. In fact, little if any increase could have been expected as one of the heaviest pickings of fruit was made on the day the experiment started and nearly all the crop was harvested by September 1. Based on preservation of the foliage, however, Bordeaux mixture seemed to rank first, with copper soap calcium arsenate dust and Sanders' Bordeaux dust, a close second and third. As Bordeaux mixture is one of the most effective spray substances ever used and as Sanders' Bordeaux dust is being successfully substituted for it in Nova Scotia, Canada, and in some parts of the United States, the showing made by copper soap dust in comparison with these fungicides looks very promising.

## DISCUSSION

There is much need of an economical dust fungicide that will give as effective results as liquid Bordeaux mixture. Although many dusts have been tried, none with the possible exception of Sanders' Bordeaux, has given as good results for general use as liquid Bordeaux.

Copper soap dust seems promising but its merits can not be definitely determined until it is thoroughly tested on a large number of foliage diseases. It has some advantages over Sanders' Bordeaux, as it spreads more evenly and floats and adheres better. Moreover, it is free from a lot of inert material commonly present in most dust fungicides, and therefore distributes the copper uniformly. Because of its light weight and floating quality, it also has a better opportunity to come into contact with the foliage than has Sanders' Bordeaux or other heavy dusts.

The copper soap dust experimented with gave good results in spite of the fact that its particles varied greatly in size. If ground uniformly fine it would not only have greater covering capacity but should give better results.

Copper soap dust will probably cost about as much as Sanders' Bordeaux if, as these experiments seem to indicate, 15 pounds of copper soap dust are as effective as 30 pounds of Sanders' Bordeaux. As 13.2 pounds of copper soap dust gave as good control of Septoria leaf spot in 1919 as 100 gallons of 4-4-50 liquid Bordeaux mixture, 15 or 16 pounds per acre may suffice for the control of tomato foliage diseases. If on this estimate we compare the cost of dusting with copper soap and lead arsenate with

that of spraying with 4-4-50 liquid Bordeaux mixture and lead arsenate, even at the rate of 50 gallons of mixture per acre instead of 100 gallons as used in the experiments, the relative costs per acre are given in table 2.

TABLE 2

*4-4-2-50 Bordeaux lead arsenate mixture*

| 50 gallons per acre | 1 application | 5 applications |
|---|---|---|
| 4 lbs. copper sulphate at 10c | $0.40 | $2.00 |
| 4 lbs. lime at ½c | .02 | .10 |
| 2 lbs. lead arsenate at 40c | .80 | 4.00 |
| * applications of 50 gals. at 2c | 1.00 | 5.00 |
| | $2.22 | $11.10 |

*1-6-1 copper soap lead arsenate dust*

| 16 lbs. per acre | 1 application | 5 applications |
|---|---|---|
| 2 lbs. copper sulphate at 10c | $0.20 | $1.00 |
| 12 lbs. resin fish-oil soap at 6c | .72 | 3.60 |
| 2 lbs. lead arsenate at 40c | .80 | 4.00 |
| * application 16 lbs. at ½c | .08 | .40 |
| | $1.80 | $9.00 |

By dispensing with the insecticide the expense of using either fungicide would be reduced 80 cents for each application or $4.00 for five applications.

The estimated cost of using copper soap dust is less than for the use of liquid Bordeaux mixture but no allowance has been made for grinding and mixing. On the other hand, the cost of Bordeaux has been calculated on the basis of 50 gallons an acre, while it was used in the experiments at the rate of 100 gallons an acre. Moreover, the writers have found that 50 gallons an acre are not so effective in the control of tomato leaf spot (*Septoria lycopersici*) as 100 gallons.

Copper soap dust of the 1-6 formula should be tested both with and without the addition of lead arsenate for the control of foliage diseases of a large number of crops. Although the other formulas and mixtures should also be tried, they should not be used on a commercial scale until their properties are better known.

## SUMMARY

Copper soap dust, a new fungicide prepared from copper sulphate and fish-oil soap, has for two years at the the Arlington experimental farm

* The estimated cost of application by Sanders and Kelsall (Proc. Entomol. Soc. of Nova Scotia, 1918, p. 32) is 2 cents a gallon for liquid and ½ cent a pound for dusts, but this is probably low for spraying and dusting field crops. However, if a 6-row duster were used the cost of dusting would be very little per acre.

given as good control of tomato leaf spot (*Septoria lycopersici*) as 4-4-50 liquid Bordeaux mixture. It spreads, floats, and adheres better than Sanders' Bordeaux dust and in these experiments gave better control of tomato leaf spot. As it is much more effective pound for pound than Sanders' Bordeaux, it will probably cost no more per acre. Moreover, it is cheaper than liquid Bordeaux, considering the cost of application, and is much more easily and quickly applied. Because of its excellent chemical, physical, and fungicidal properties, it offers promising possibilities for the control of a large number of other foliage diseases.

OFFICE OF COTTON, TRUCK AND FORAGE
CROP DISEASE INVESTIGATIONS
BUREAU OF PLANT INDUSTRY
WASHINGTON, D. C.

# STUDIES ON THE VALSA APPLE CANKER IN NEW MEXICO

LEON H. LEONIAN

Some specimens of cankered apple branches were sent to the New Mexico Agricultural Experiment Station from Socorro county, N. M. in the winter of 1919. The farmer, who submitted them, claimed that a large number of his trees, both young and old were rapidly being killed by the disease. The following spring the same canker made its appearance on the apple trees of the Station farm, and furnished ample material and opportunity to study the disease. A preliminary survey showed that the canker was present in almost every apple growing section of New Mexico, and that it was believed by the growers to be very troublesome.

### THE DISEASE

The canker appears on the twigs, the branches, and the main trunk of young or old apple trees. If the point of primary infection is on the twig, the canker spreads downward and into the branches and the trunk; but if it is on the trunk, it spreads upward, but more slowly, and before it reaches all the branches, the trunk may be completely girdled.

The disease shows itself first by forming discolored, sunken lesions which may extend along the entire length of the branches and eventually affect all sound tissues. The area between the diseased and the healthy wood is well marked by the discolored and sunken nature of the invaded region, by a wrinkled, peeling and split epidermal border, and often by the appearance of a purplish zone which usually marks the advance of the fungus. The infected bark is at first water-soaked, and the epidermis can readily be rubbed off exposing darkened tissues beneath. The fruiting bodies of the fungus appear over the entire cankered area, generally one or two weeks after the forming of the lesions. The symptoms on the trunk are somewhat different; the water-soaked bark becomes soft, swollen, and of cheesy consistency when pressed with the fingers. Gradually, however, it dries and sinks back to the level of the unaffected tissues. As the drying progresses, it shrivels still further, while the border between the cankered and the healthy parts cracks, and the loose epidermis gathers itself into semi-transparent wrinklings.

[1] Published by the permission of the Director of the New Mexico Agricultural Experiment Station. The writer wishes to express his thanks to Dr. C. H. Kauffman for his critical reading of the manuscript and helpful suggestions.

If the canker is on the trunk, the tree gradually turns sickly looking, the leaves remain small, fade into a faint green, then become yellowish and drop off. The fruit remains undersized, juiceless, and soon falls. Neither a sudden, nor even a gradual wilting has been observed. Somewhat different effects result when the canker starts on the branches; the affected tissues dry more rapidly, and defoliation takes place much faster. The canker extends from branch to branch, but its rate of advance depends entirely upon the condition of the tree, so that often the final destruction may not be accomplished before two or even more years.

## THE FUNGUS

The fruiting bodies of the fungus responsible for the canker are largely pycnidia, with well developed, convex, multipycnidial stromata, and hyaline, non-septate, allantoid conidia. In this stage it is, therefore, a species of Cytospora. To refer this fungus to the proper species presented a difficult problem because of the very large number of closely resembling forms classified under this genus. At first a careful search for the perfect stage of the fungus met with negative results. Meanwhile Stevens (6) published a bulletin in which he discussed a similar canker of the apple caused by a species of Cytospora. Some samples of cankered specimens and pure cultures of the causal organism were sent to Dr. Stevens for comparison, and he declared the organisms to be identical. Finally the writer's search for the perfect stage of the fungus was rewarded by discovering a small patch of fruiting bodies which proved to be the perithecia of a Valsa species resembling *Valsa leucostoma* (Pers.) Fr. as described so extensively by Aderhold (1) and Rolfs (3, 4, 5).

## IN CULTURE

The relationship of the perfect to the imperfect form of this fungus was established by pure cultures and inoculation experiments. Ascospore isolations upon steamed apple twigs gave rise to both the Cytospora and the Valsa type of fruiting bodies. When conidia thus obtained were transferred to another series of steamed apple twigs, they yielded nothing but pycnidial stromata, while similar cultures with ascospores produced both pycnidia and perithecia. Inoculation experiments in the field with the conidia and the ascospores of this fungus, as well as with conidia obtained from pure cultures of a plum strain of *Cytospora leucostoma*, gave rise to lesions and fruiting bodies identical with those found on the cankered apple branches in the orchard. Pure cultures of *Cytospora chrysosperma* (Pers.) Fr. were used as checks and were found to be unable to affect the apple trees. When grown on apple branches, the plum strain of this fungus lost the characteristic white substance which

ordinarily crowns its ostioles, and its stromata no longer adhered to the epidermis, but became more closely imbedded in the bark. In the New Mexico climate the apple strain of this fungus does not show any white, powdery substance on the ostioles; but in test tube cultures, where the moisture conditions have been controlled carefully, it appears. This white substance is nothing more than masses of stromatic hyphae which being exposed to the air, dry and become powdery. The epidermis of the affected apple branches either does not rupture under the pressure of the enlarging stromata beneath, or else it merely cracks, without, however, opening wide enough, as is the case with that of the plum trees, to expose the gray stromatic masses. Probably the epidermis of the apple branches is more elastic and tenacious. In test tubes, however, where moisture conditions are properly controlled, the stromatic tissues expand more forcefully and overcome the resistance of the epidermis, pushing out the gray masses through the cracking and yielding host tissues.

The mycelium of this fungus grows well and pycnidia form readily on oatmeal and cornmeal agars, on potato hard agar containing five per cent glucose, and on steamed apple twigs and sweet clover stems. Very sparse mycelial growth and no pycnidial development was observed on nutrient gelatin (+ 1). On nutrient agar [2] the mycelium was mostly submerged, moist, and very poor. Some dark, olivaceous hyphae formed compact, wrinkled crusts very similar to pycnidial walls, but no spores were ever found in these. When the quantity of agar-agar was raised to seven per cent or more, however, and even on pure agar-agar, a few undersized stromata containing mature pycnidia developed. Coon's (6) synthetic solution [3] made solid by adding 1. 5 per cent agar-agar, was found to induce the formation of a very few mature pycnidial fruiting bodies. The mycelium made a poor growth on this agar, however, and mature pycnidia were not observed until fifteen days after the time of inoculation, whereas on cornmeal and oatmeal agars the first fruiting bodies appeared within four days, and a week later the entire slant of the agar became thickly warted with well developed fruiting bodies. On

[2] Ammonium nitrate 1 gm., dihydrogen potassium phosphate .5 gm., magnesium sulphate .25 gm., iron chloride trace, cane sugar 5 gms., agar-agar 1.5 gm., water 100 c.c.

[3] "Magnesium sulphate + 7 aq. 2 46 gms., in 50 c.c. water; potassium acid phosphate 1.36 gms. in 50 c.c. water; asparagin 1.33 gm. in 50 c.c. water; maltose 3.60 gms., in 50 c.c. water. For 100 c.c. synthetic solution take 1 c.c. magnesium sulphate, 5 c.c. of each of the other solutions and add to 84 c.c. water. Steam in Arnold's steriliser for three successive days." Wherever in this paper reference is made to Coon's media, it should be understood that the solution was made solid by the addition of 1.5 per cent. agar-agar.

steamed apple twigs which did not contain a very large amount of moisture, the stromata developed normally, and except on the cut ends of the twigs, no hyphal growth could be seen. When the moisture content was too high, however, and the air in the test tubes was saturated with water vapor, the stromata became entirely superficial, strongly globose, often verruciform, and coated with a gray to olive green hyphal velvet. On artificial media and in a very moist atmosphere the pycnidial stromata became stalked. At first a number of hyphal wefts appear; these form slender pillars two to three mm. tall. The upper parts of these branch out into cottony, loose heads in the form of bouquets. Later, in the central portion of these heads there appear some olivaceous hyphae which become compact, round up and form mature stromata. Often more than one stroma may appear, supported by the same column.

Numerous attempts to obtain perithecia on oatmeal agar failed until the composition of the media was changed by the addition of various amounts of sugar. Three weeks after inoculation with ascospores the entire slant of the agar containing sugar became bristling with the beaks of the perithecia. The number of perithecia increased and that of pycnidia with the gradual augmentation of the sugar content. The period for the formation of perithecia was lengthened, however, with the higher concentrations of sugar, so that while on media with 2 per cent cane sugar the perithecia appeared within 10 to 12 days, on those with 8 to 12 per cent of sugar they were delayed for more than a month. Different results were obtained on cornmeal agar; perithecia formed readily on this when it contained no sugar, while an addition of more than 2 per cent sugar delayed, or even inhibited their formation. Sodium chloride added to oatmeal agar acted the same way as cane sugar, although in this instance the period of perithecial development was lengthened to five weeks. Enough sodium chloride and cane sugar were weighed to make M/16 solutions of each, and added to two separate lots of oatmeal agar. In case of oatmeal agar containing sugar a great abundance of perithecia was observed in about three weeks, while in case of oatmeal agar containing sodium chloride, five weeks after an equally large abundance of perithecia was obtained. The checks, to which neither sugar nor salt were added, produced pycnidia only, although after three months desiccation in the laboratory, about half a dozen perithecia formed on the driest edge of this media.

Interesting results were obtained when cultures of this fungus were transferred from one solution to another. A new cultural method was devised to conduct these experiments. The basic principle of this was derived from Coon's (2) filter paper cone system. He grew his fungus on filter paper cones kept in glass capsules which contained some nutrient

solution. While this method makes it possible to transfer the entire growth of a given fungus from one solution to another without disturbing the mycelium, it confines the investigator to liquid cultures, failing, at the same time, to eliminate the disadvantages of the old methods,namely the evaporation of the water from the media and the consequent increase of its osmotic pressure. The following variation of the cone method has therefore been used; filter paper cones of any desired size are made, the apex of the cone is moistened and pushed in with the finger to give it a cup-like appearance, then glass capsules of suitable size are selected and filled two-thirds with distilled water, one cup being placed in each and sterilized. Any solid media can then be poured into the cups. Care should be taken to pour just before it begins to jell, else it may filter through the cone. With this treatment the moisture content of the media was observed to remain practically the same during the expreiment. This was due to the fact that water from the capsule passsed up into the media by capillarity and replaced the evaporating moisture.

When the cultures, in Coon's synthetic media (3) were repeated in the laboratory at Ann Arbor, it was found that the pycnidia were slower to appear. They developed at least two weeks later than under similar cultural conditions in the New Mexico laboratory. It was found that their development could be hastened considerably by adding cane sugar or sodium chloride to the media, as follows: the synthetic media was poured in filter paper cups which were kept in glass capsules containing distilled water. Six days after inoculation the cultures were divided into three lots; one served as check, while the cups of the second lot were transferred, by means of flamed forceps, to other sterile capsules containing M/16 sodium chloride solution, and those of the third lot were transferred to capsules with M/16 cane sugar solution. Ten days later a fair number of pycnidia formed on the media of the second and the third lot, while in case of the checks no pycnidia developed even after one month.

TABLE 1

*Culture cups used with solutions*

| | | |
|---|---|---|
| Set 1. | Check. | Culture cups allowed to remain in distilled water. |
| Set 2. | Check. | Culture cups allowed to remain in M/16 cane sugar solution. |
| Set 3. | Check. | Culture cups allowed to remain in M/16 sodium chloride solution. |
| Set 4. | | Cultures transferred from distilled water to M/16 cane sugar solution. |
| Set 5. | | Cultures transferred from distilled water to M/16 sodium chloride solution. |
| Set 6. | | Cultures transferred from M/16 sugar solution to distilled water. |
| Set 7. | | Cultures transferred from M/16 sodium chloride solution to distilled water. |

Since the synthetic media failed to induce the formation of the asci-

gerous stage, and since oatmeal agar reacted so well when it contained either salt or sugar throughout the growth of the fungus, it was believed that when subjected to the action of sodium chloride or sugar temporarily, it would produce interesting variations in the fungus. With this end in view the following experiments were made: a series of filter paper cup cultures were made and the cups were filled with plain oatmeal agar. Some of the capsules contained distilled water, others M / 16 cane sugar solution, and a third lot M / 16 sodium chloride solution. Thus in one case the oatmeal agar received distilled water through the capillary action of the filter paper, in the second case it imbibed sugar, and in the third sodium chloride. All of these cultures were inoculated on the same date. Six days after, when the fungus had made a fair growth but no fruiting bodies had appeared as yet, the cultures were transferred from one solution to another as described in the foregoing table. All sets were in duplicate, and the experiments with the sugar were repeated. The cultures were washed in distilled sterile water before transferring from salt or sugar solutions to water.

Four days after the transfer, or ten days from the time of inoculation, pycnidia developed in all of the seven groups. It seems that the necessary stimulus for their formation was present in the oatmeal itself, and the addition of salt or sugar could have no marked effect. Entirely different results, however, were obtained in case of perithecia formation, as can be seen in the following table;

TABLE 2

*Effect of above treatment of cultures on formation of perithecia*

| | |
|---|---|
| Set 1. | No perithecia, even after 36 days. |
| Set 2. | Perithecia formed in 29 days. |
| Set 3. | No perithecia, even after 36 days. |
| Set 4. | No perithecia, even after 36 days. |
| Set 5. | No perithecia, even after 36 days. |
| Set 6 | Perithecia formed in 18 days. |
| Set 7 | Perithecia formed in 29 days. |

It can be seen, from the foregoing table, that the necessary stimulus for the formation of the perfect stage will have to be furnished from the very beginning of a period limited to 36 days, and that the absence of the stimulus for the first six days will be sufficient to suspend perithecia formation, even though it is furnished at the end of that period. The constant presence of sugar or sodium chloride retards the formation of the ascigerous stage for a considerable period. It will also be noted that in filter paper cup cultures perithecia require a longer period to appear than

they do in test tubes. Perhaps the gradual drying of the media in the test tubes is responsible for this effect.

## PATHOGENICITY

To the casual observer this fungus will appear to be a parasite of great physiological efficiency. According to Stevens (6) "it appears that this canker is one of very rapid development and one that might cause serious loss should it become widespread." He made inoculations on apple and other twigs in test tubes with a few centimeters of water to keep the cultures moist and alive, and he obtained a ready growth and fruiting of his fungus. He did not care to make inoculations in the field for fear of spreading the disease. The writer selected a number of apple trees in the Station orchard, and inoculated them with pure cultures of this organism. Some of the trees were vigorous, others weak and gradually dying. Twigs, branches and trunks were inoculated with either conidia or ascospores. The inoculations were made through wounds in case of some trees, while no wound was made in case of others. None of the healthy trees showed any sign of infection even four months after the inoculation. In case of the weaker trees, however, the wound inoculations developed the canker within ten days, while none of the inoculations made on the sound tissues and given all the favorable conditions for infection, gave any positive result. Within a period of six weeks the fungus progressed from the tips of the twigs into the branches, the limbs, and the trunks, forming an abundance of typical fruiting bodies as it advanced. The rate of the progress of the canker was always governed by the condition of the tree; it was rapid if the tree was weak, and slow if it was less severely affected.

All trees which showed canker, either as a result of natural infection or of artificial inoculation, were dug out to determine the cause of their weakened condition. It was found that in all cases the roots were badly infected with the wooly apple aphis, or the underground trunk was almost completely girdled by the giant apple tree borer. Often both of these injuries were found to be associated. The organism which causes the canker, therefore, so far as conditions in New Mexico are concerned, is not a parasite to be feared, at least not for the time being. The same thing is true in case of plum and peach trees, which, if well cared for, never show any canker caused by *Cytospora leucostoma*. Old and neglected trees are the only ones which can be affected by this organism.

## SUMMARY

A great number of apple trees throughout New Mexico were found to be badly affected with a canker caused by *Valsa leucostoma* (Pers.) Fr.

Twigs, branches, limbs, trunks may be attacked by the fungus with equal ease. Both the imperfect and the perfect stages of the organism responsible for the canker were reproduced in artificial media. Sodium chloride and cane sugar, under proper conditions, acted as stimuli to form perithecia on oatmeal agar.

Inoculation experiments showed the fungus to be a weak wound parasite.

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# TOLERANCE TO ACIDS OF CERTAIN BACTERIAL PLANT PATHOGENES.

FREDERICK A. WOLF AND I. V. SHUNK

## INTRODUCTION.

Cultural studies of plant pathogenic bacteria are generally believed to be incomplete unless they include a determination of the lethal or limiting hydrogen and hydroxyl ion concentration. Recent investigations on forms pathogenic to man have demonstrated, by the employment of refined methods, the importance and value of hydrogen ion determinations. Similar studies by plant pathologists, employing methods of precision in measuring acidity and alkalinity, in place of the meaningless titrimetric methods, would no doubt show that H-ion concentration is of significance in the culture of plant pathogenic forms. Certainly in such an important problem as the possible correlation between tolerance to acid and immunity or resistance no progress has been made with methods in vogue and no convincing body of evidence has thus far been adduced. Neither will such data be forthcoming until a better understanding is had of some of the fundamental factors underlying the inhibitory or antiseptic action of acids.

Further, the influence of the hydrogen ion inhibition of growth and on the processes of metabolism in bacteria is generally believed both to be specific and an easily explicable matter. It becomes obvious, however, that such is not the case, and that much additional experimentation is necessary before an adequate explanation can be offered for the phenomena which may be noted if one cultivates several species of bacteria on media which differ only in the kind of acids employed in making the pH adjustment.

In the present investigation, attention has been directed to the nature of the acid and to the nature of the medium as factors in the problem of the influence of pH. There has arisen, outside the field of plant pathogenic bacteriology, a considerable body of literature dealing with inhibition and antiseptic action. Some of these investigations, as will be discussed later, point out the interesting fact of the failure of acids of the same pH concentration to inhibit cell multiplication, the cause of which has not been satisfactorily explained. This observation has been confirmed in the present study with plant pathogenic forms and in addition, differences in growth in liquid and solid media are noted which further indicate the complexity of the problem of inhibition.

## METHODS

The organisms employed were *Bacillus carotovorous*, *Bacterium campestre*, *Bacterium angulatum*, *Bacterium tabacum*, *Bacterium glycineum* and *Bacterium sojae*. They were cultivated in bouillon consisting of 1 per cent Armour's peptone, 0.3 per cent Liebig's beef extract and 0.5 per cent NaCl and in nutrient agar prepared by adding two per cent agar to the bouillon. Two per cent of agar and 1 per cent of peptone were arbitrarily employed after some preliminary experimentation upon the effect of variation of the agar content and of the peptone between 1 and 3 per cent. As is well known, both of these substances, except in the case of pure agar modify the "buffer" action and consequently the amount of acid necessary to secure the desired pH but within the range of 1 to 3 per cent, they appear to be without effect on inhibition of growth.

After dissolving the materials, the media were neutralized, flasked in 200 c. c. quantities and sterilized. As soon as they had cooled to about 60 ° C, commercially pure concentrated acid of the appropriate kind was added, using aseptic precautions, to obtain the desired pH values. The pH values were determined colorimetrically by comparison with buffer color standards. These buffer solutions were checked electrometrically and were found to be less than their assigned value by .03 to .06 pH. After the media had been adjusted to the desired H-ion concentration, they were poured into sterile test tubes. Such a procedure as demonstrated in a previous paper (5) is of especial value in the preparation of solid media since it removes the necessity of sterilization after adjustment of reaction and thus does not modify the acidity nor destroy the jellifying power. All tubed media were incubated for 48 hours before inoculation to determine their freedom from contamination.

## RESULTS

Growth in bouillon, as shown in table 1, was determined by the ability of the several organisms to cloud the media. In the case of abundant clouding, the sign + is employed, no visible growth is indicated by — and a slight clouding by —+.

Manifestly the H-ion concentration alone does not determine the limit of tolerance of these organisms since one would then expect irrespective of the acid, cellular multiplication to be checked at the same point. The several organisms are seen to be more tolerant to malic than to any other of the acids and to be inhibited most by acetic. At a pH value of 4.6, when malic acid was employed *Bacterium tabacum* made a slight growth, whereas with acetic acid, the limit lies between 5.8 to 6.0. In the case

**TABLE I**

*Tolerance of various organisms to acid in bouillon*

| Name of Organism | pH 4.6 | | | | | | | pH 4.8 | | | | | | | pH 5.0 | | | | | | | pH 5.3 | | | | | | | pH 5.5 | | pH 5.8 | pH 6.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hydrochloric | Sulphuric | Acetic | Citric | Tartaric | Malic | Formic | Hydrochloric | Sulphuric | Acetic | Citric | Tartaric | Malic | Formic | Hydrochloric | Sulphuric | Acetic | Citric | Tartaric | Malic | Formic | Hydrochloric | Sulphuric | Acetic | Citric | Tartaric | Malic | Formic | Acetic | Formic | Acetic | Acetic |
| Bacterium campestre | — | — | — | — | — | — | — | — | — | — | — | — | + | — | — | — | — | + | + | + | — | + | + | — | + | + | + | — | — | + | + | + |
| Bacillus carotovorus | — | — | — | — | — | — | — | — | + | — | —+ | — | + | + | + | + | — | + | + | + | + | + | + | + | + | + | + | + | — | | + | + |
| Bacterium glycineum | — | — | — | — | — | — | — | — | — | — | — | —+ | + | — | + | — | — | + | + | + | + | + | + | — | + | + | + | + | — | | — | + |
| Bacterium sojae.... | — | — | — | — | — | — | — | — | — | — | —+ | — | + | — | + | — | — | + | —+ | + | + | + | + | — | + | + | + | + | — | | — | —+ |
| Bacterium angulatum | — | — | — | — | — | — | — | — | —+ | — | —+ | —+ | + | — | + | + | — | + | + | + | + | + | + | — | + | + | + | + | — | | — | + |
| Bacterium tabacum. | — | — | — | — | — | —+ | — | — | + | — | — | —+ | + | — | + | + | — | + | + | + | + | + | + | — | + | + | + | + | — | | — | + |

TABLE II

*Tolerance of various organisms to acids in agar*

| Name of Organism | pH 4.4 | | | pH 4.6 | | | pH 4.8 | | | | pH 5.0 | | | | pH 5.4 | pH 5.5 | pH 5.6 | pH 5.8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hydrochloric | Sulphuric | Oxalic | Hydrochloric | Sulphuric | Oxalic | Hydrochloric | Sulphuric | Oxalic | Acetic | Hydrochloric | Sulphuric | Oxalic | Acetic | Acetic | Acetic | Acetic | Acetic |
| Bacterium campestre | — | — | — | — | — | — | —+ | + | + | — | + | + | + | — | — | --+ | + | + |
| Bacillus carotovorus | — | —+ | — | + | + | + | + | + | + | — | + | + | + | + | + | —+ | —+ | + |
| Bacterium glycineum | — | — | — | — | + | — | —+ | + | — | — | + | + | + | — | — | — | — | + |
| Bacterium sojae | — | — | — | — | — | — | + | + | — | — | + | + | + | — | — | — | — | + |
| Bacterium angulatum | — | — | — | — | — | — | + | + | — | — | + | + | + | — | — | — | — | + |
| Bacterium tabacum | — | — | — | — | — | — | —+ | + | — | — | + | + | + | — | — | — | —+ | + |

of *Bacillus carotovorus*, inhibition by these two acids occupies a much more restricted range since growth was checked between 4.6 and 4.8 by malic acid and 5.3 is the corresponding limit with acetic acid. *Bacterium campestre* is considerably more intolerant to formic acid than is *Bacillus carotovorus* since 5.5 and 4.8 represent the respective limits.

Differences in vigor of growth on the agar slants are indicated by the same signs and the data are summarized in table 2.

The most striking fact exhibited by growth on solid media as contrasted with liquid media is the ability of the several organisms to withstand a greater H-ion concentration when grown on the former. In general, this difference appears to vary from 0.2 to 0.4 pH. Just as in liquid media, all organisms are less tolerant to acetic than to the other acids, *Bacillus carotovorus* appears to be considerably less sensitive to acetic acid, however, than any of the other organisms since its limit lies between 4.8 and 5.0 and the others between 5.5 and 5.8.

## DISCUSSION

The fact that acids of different hydrogen ion concentration can exert a similar influence in checking bacterial growth has previously been noted, as has been indicated. Winslow and Lochridge (4) using *Bacillus coli* and *B. typhosus*, found that the disinfecting power of acids was proportional to the concentration of the hydrogen ion, but noted in the case of acetic acid an effect greater than that due to the H-ion concentration. In explanation, they suggest that this is due to the undissociated acid remaining in the solution. More recently, Cohen and Clark (1) from cultural studies on *B. coli* pointed out that the factor or factors which obscure the effect of the H-ion are quite unknown. They noted that this organism grew well at pH 5.0 when adjustment was made with HCl but at pH 5.45 with acetic acid the same organism declined in numbers. Other organisms exhibited the same difference in conduct with reference to these two acids. They explain this as probably due to a synergic effect of the free acetate radicle upon the disinfecting power of the hydrogen ion, a view in accord with those who hold that the anions and undissociated molecules play an important role in the kinetics of disinfection by accelerating the action of the hydrogen ion. They also suggest the probability that this difference corresponds to a difference in permeability of the organism to mineral and organic acid.

Were one in possession of full knowledge of the unknown factor involved in the foregoing observations, he could no doubt explain what is believed to be a comparable condition reported by Svanberg (3). He found that *Streptococcus lactis* (*Bacterium lactis acidi*) in milk is capable of producing an acidity which corresponds to the value pH=4. When

however, lactic acid is added to milk, growth is checked at pH = 4.4 to 4.7 and acetic acid at pH = 4.8 to 5.1.

The plant pathogens used in the present investigation appear to respond differently toward the various acids just as did the several organisms employed in these several studies. This may be taken to indicate that the various acids exert a specific effect. Granted that the effect is specific, it is not clear how one could employ this fact in explaining the general shift of the limit of tolerance of 0.2 to 0.4 pH as occurs between bouillon and nutrient agar. It is felt, however, that this observation should be reported at this time on its own merit, subject to verification, and with the admission that no adequate explanation of the cause is known to us. It is believed that the fact of a greater pH tolerance on solid media is of significance in studies which attempt to correlate the acidity of juices of certain plants with tolerance in culture of forms parasitic on these same plants.

In conclusion, the present studies appear to be in accord with several others previously discussed in showing that the activity of the hydrogen ions alone is not responsible for the inhibitory effects which have been observed. This is opposed by the conclusions of a number of investigations, among which are those of Norton and Hsu (2) who inclined to the view that the disinfecting power of an acid is approximately proportional to the hydrogen ion concentration. Whatever may be the ultimate solution of this problem, it is apparent that further developments will depend upon the devising of methods which will show what are the dissociation products of the various acids in such complex solvents as bouillon or agar and whether or not these dissociation products in the presence of the H-ions modify the permeability of the bacterial cell wall.

## SUMMARY.

Cultural studies have been made on the tolerance to acids of various plant pathogenic bacteria including the cabbage black rot organism, one commonly causing decay of root crops, two causing leaf spots of soy bean and two causing tobacco leaf spots.

Different acids of the same H-ion concentration are not able to exert the same influence in inhibiting cell multiplication. Acetic is more toxic than any other of the acids employed, an observation which accords with that of others.

A greater pH concentration in agar than in bouillon is required to inhibit growth, this difference ranging between 0.2 and 0.4 pH with the same organism and the same acid.

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## PHYTOPATHOLOGICAL NOTES

*Fiji disease of sugar cane in the Philippine Islands.*—Fiji disease of sugar cane, previously reported only from the Fiji Islands, New Guinea, and Australia, has been found in the Philippine Islands. It was found on the Island of Mindoro simultaneously by Professor Reinking of the College of Agriculture, University of the Philippines, and the writer. Later the disease was found in Laguna and Batangas Provinces and was there identified by Mr. H. Atherton Lee, just returned from Honolulu where, through the kindness of Dr. H. L. Lyon of the Experiment Station, Hawaiian Sugar Planters' Association, he had the opportunity of examining preserved specimens of the disease from Fiji. There can be no question as to the identity of the disease.

The varieties Hawaii 109 and Java 247 are rather severely affected. Yellow Caledonia, Louisiana Striped and the native cane varieties Luzon White, Pampanga Red, and Cebu Purple were all affected, but at this time appear to have a slightly lesser degree of susceptibility.

In provinces where the disease is found, considerable losses have been caused on all of these varieties. One field of Yellow Caledonia plant was so severely affected that it wasplowed under. In other fields, plantation managers estimate their losses at from 25 to 50 per cent, although the writer believes these losses possibly are a little over estimated. The losses from the disease are apparently increasing from year to year. The ratoon fields seem to show more of the disease than fields of plant cane.

To minimize or entirely prevent the losses from the disease, the following measures have been taken:

(1) The Plant Quarantine Board of the Philippine Islands has issued a regulation prohibiting the movement of all cane materials from Mindoro, Laguna, and Batangas Provinces. No case of the disease has been reported as yet in Negros, the large sugar-producing island; nor has it been reported from Cebu or Mindanao. In the absence of a definite report of the disease in those islands the domestic quarantine of the affected provinces seems justified.

(2) In cooperation with plantation managers in quarantined localities, steps are being taken to furnish seed points from disease-free fields, to planters whose fields are affected.

(3) Through the kindness of Dr. H. L. Lyon information has been made available concerning resistant varieties. Dr. Lyon states that Badila, Rose Bamboo, and Striped Singapore varieties, although not

immune, exhibit a degree of resistance to the disease. These varieties are available at the Plant Pathology laboratories and will be distributed in small amounts to planters in affected localities.—MARIANO G. MEDALLA.

*The susceptibility of Dwarf Milo sorghum to smut.*—The smuts of sorghum are of such an economic importance in India that in the Bombay Presidency alone, the annual losses caused by them exceed a million sterling. As most of the known varieties of sorghum are susceptible to smut the discovery of any immune variety will be a real boon to the cultivator. Attempts of this line of work have so far not been met with any success [1]. The writer's attention was drawn to the statement, occurring in the Journal of Agricultural Research.[2] "Fortunately the widely-grown variety, milo, has proved immune from all the smuts of sorghum" and he was therefore tempted to verify the statement. Accordingly the American authorities were requested to supply small quantities of seed of different kinds of milo sorghum. The result was complied with by supplying him with the seed of only one variety, Dwarf Milo[3] which was tried at the Agricultural College farm at Poona, India.

Before sowing, the seed was infected with the fresh spores of grain smut (*Sphacelotheca sorghi*) and loose smut (*Sphacelotheca cruenti*) [4]. Infection of the seed was effected by sprinkling the spores on the seed. The seed was sown June 19, 1920, and produced 635 heads of grain. Of these, 3 heads were affected by grain smut and 50 heads by loose smut; or 0.47 and 7.8 per cent respectively. It may therefore be said that Dwarf Milo sorghum is resistant but not immune to the grain smut, but is decidedly susceptible to the loose smut.—G. S. KULKARNI.

*Personals.*—Miss E. M. Wakefield, F. L. S., mycologist at the Kew Botanical Gardens, has finished a number of months' work in the British West Indies. On her way home she is visiting botanical institutions at New York; Washington, D. C.; Columbus, Ohio; St. Louis, Mo.; Toronto; Ithaca, N. Y.; and Boston. While in Washington she was tendered a dinner by the women mycologists and pathologists of the U. S. Department of Agriculture.

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[2] Potter, A. A. Head smut of sorghum and maize. Jour. Agric. Res. 2: 368. 1914.

[3] Thanks are due to Dr. David Fairchild and G. P. Van Eseltine.

[4] Four kinds of smut occur on sorghum: Grain smut, loose smut, whole head smut, and long smut (*Polyposporium filiferum*). Of these the first two are important.

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# PHYTOPATHOLOGY

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## PHOMA ON SWEET SORGHUM


Elizabeth Koch and Caroline Rumbold


With Plates IX to XI and Three Figures in the Text

### DISTRIBUTION AND OCCURRENCE OF THE DISEASE

*On leaves.* In 1917, this laboratory received some diseased sorghum plants, which had leaves infected with Phoma. The plants had been collected August 21 at Fort Smith, Arkansas; September 15 at Manhattan, Kansas; October 6, in Choctaw County, Mississippi, and on October 31, at Laredo, Texas. In 1918 the laboratory received a few sorghum plants collected September 6, at Ratcliffe, Arkansas, with leaves infected with Phoma. In 1920 three different lots of diseased seedlings were received from Arkansas. One lot was collected near Ursula on July 20, the other two lots from the neighborhood of Fort Smith, July 28. In one lot, which came from near Fort Smith, the seedlings had yellow leaves and well developed Phoma pycnidia were found in the discolored areas. The other two sets of plants had green leaves, but when cultures were made from them, were found infected with Phoma. On August 30, 1920, the junior writer collected Phoma infected leaves from the Black Amber, Early Amber, Planter's Friend, Silver Top, and Japanese Ribbon varieties of sweet sorghum growing on the Government farm at Arlington, Va.

*On seeds.* Mr. H. B. Cowgill, of the Office of Sugar-Plant Investigations, kindly furnished seed of varieties of sweet sorghum grown on the experimental plots at Fort Smith, Arkansas. During the winter of 1919-20, five varieties: Planter's Friend, Sapling, Collier, Orange and Red X were found infected with Phoma. Pycnidia were found also on the glumes of Planter's Friend and on the seed stems of Red X. During the winter of 1920-21 he furnished additional varieties of sweet sorghum seed from the same source. Examination showed Phoma fruiting on Albaugh Early, U. S. Colman, Fort Scott Colman, Fort Smith Colman, Farmer Jones, Honey, Indiana Amber, Minnesota Amber, Sugar Drip and McLean (1919 harvest). Pycnidia were found on the glumes of Red Amber, Minnesota Amber and Japanese Ribbon and the lemma of Silver Top seed.

In view of the widespread occurrence of the Phoma on sweet sorghum

and its persistence year after year, it was thought a more detailed knowledge of the life history of the fungus would be of value.

### GENERAL APPEARANCE OF DISEASED SEED AND LEAF

To the unaided eye the fungus looked like a fine dust on the seed coat and on the leaf, giving them a dirty appearance. (A quick way of telling whether a leaf or seed was infected was to rub it off with the thumb. The dirt rubbed off, while the pycnidia, being embedded in the host tissues, stood out, plainly in view).

The seed did not show discolored spots, the pycnidia were scattered and often had formed on the epidermis in a line just above the edge of the glume. (Pl. XI.) Usually the infected areas on the leaves were yellow or tan colored and dry. These areas were irregular in shape, sometimes indefinite in outlines, sometimes bordered by black or red lines. (Plate IX.) Rarely mature infected leaves were normal in color. The infected leaves of inoculated seedlings usually turned yellow as the pycnidia formed. (Fig. 1.)

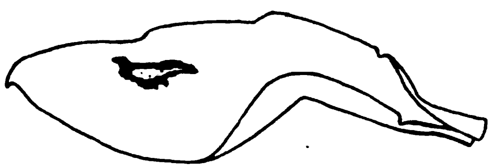


FIG. 1. LEAF OF AN EARLY AMBER SEEDLING INOCULATED WITH CONIDIA OF PHOMA INSIDIOSA FROM COLLIER. × 1¼.

### INOCULATION EXPERIMENTS

*Isolation of the fungus.* The cultures were started from single conidia by means of poured plates. New cultures were always started from conidia,—not made by transfers of mycelium,—as it was found that the fungus ceased to produce fruits after repeated transfers of mycelium were made. The pycnidia produced in the cultures were transferred to sterile water, crushed and the resulting suspension of conidia used for inoculating plants.

*Experimental material.* Five varieties of the sorghum seed held in the laboratory in 1919-20, were found free of Phoma pycnidia: Early Rose, Silver Top, Early Amber, Folger and Japanese Ribbon. These varieties were used in the experimental work instead of those varieties which were found infected, as the writers hoped in this way to find an immune variety of sorghum. With one exception, the plants were inoculated while in the seedling stage. The seedlings used were either growing in pots in the greenhouse or in covered glass dishes in the laboratory.

Six strains of Phoma were used because at first it was thought that there might be a difference in the virulence of the strains or that certain of the varieties of sorghum might be immune from some of them. Five of the strains were obtained from pycnidia found growing on the seed coats of Planter's Friend, Red X, Collier, Orange, and Sapling. The sixth strain used, called So 303 1, came from pycnidia on the leaves of an Early Amber plant inoculated with a Phoma obtained from the leaves of a sorghum plant grown in Arkansas.

*Method of inoculation.* After the first experiments, all inoculations were made by spraying the plants by means of an atomizer with a water suspension of conidia.

*Wounding the plants.* In a preliminary experiment part of a set of seedlings were wounded by needle pricks just before spraying; the other part was not injured. All the plants, pricked and unpricked, became infected and pycnidia developed at the same time on both sets. This experiment was repeated, but instead of conidia, mycelium was used for inoculating purposes. Again all the plants pricked and unpricked became infected. The pycnidia were longer in forming on the plants inoculated with mycelium than those with conidia. After these experiments, all inoculations were made without previously wounding the plants.

*Greenhouse experiments.* Seed of the five varieties of sorghum used in the experiments were sown in pots. Thirteen pots were prepared for each strain of Phoma and one for a check. Each pot contained three plants of each variety growing in a row. While in the seedling stage the plants were sprayed with a water suspension of conidia. Check plants were sprayed with sterile water.

The first inoculation of the sorghum seedlings in the greenhouse appeared unsuccessful. Nine days after the spraying no signs of infection were evident. The weather then changed, becoming warmer and more humid. The plants, no longer in the seedling stage, were reinoculated. Eleven days later pycnidia had developed. All the checks were free from infection.

The experiment was repeated, exactly the same method being used. The seedlings were inoculated at the same time that the older sorghum plants of the first experiment were reinoculated. On the seedlings, pycnidia were visible four days after inoculation. No pycnidia developed on the checks.

Only those plants showing pycnidia on the leaves were counted as infected. The counts of the two experiments showed that all of the six strains of Phoma could infect each of the five varieties of sorghum, though not all the plants became diseased. After the count was taken, some of

the plants which showed no signs of infection were cut and placed in damp chambers in the laboratory. Gradually the leaves yellowed and Phoma pycnidia developed. In these two experiments the development of the pycnidia seemed to be influenced by the checking of the host plants' growth and in turn the checking of the vegetative growth of the invading fungus. The older set of sorghum plants required seven more days to develop pycnidia than the younger, and as the plants were growing in the same greenhouse under the same conditions, this delay must be laid to the slower reaction of the older plants to infection. The experiment was repeated, the same method being used. The final reading was taken thirty-five days after inoculation. In this experiment the sixty five sorghum seedlings of each variety used in the previous experiments, were depleted in number, due to accidents.

TABLE 1

*Greenhouse Experiment: Plants growing in flower pots. Reading taken 35 days after inoculation of plants showing pycnidia on the leaves.*

| SORGHUM INOCULATED | INFECTION PRODUCED BY FOLLOWING STRAINS OF PHOMA[1] | | | | | | | | | | | | | | SUMMARY OF ALL STRAINS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PLANTER'S FRIEND | % | RED X | % | COLLIER | % | ORANGE | % | SAPLING | % | SO 303 1 | % | CHECK | % | | % |
| Early Amber | 7/10 | 70 | 4/10 | 40 | 4/8 | 50 | 2/9 | 22 | 8/10 | 80 | 4/10 | 40 | 0/5 | 0 | 29/57 | 51 |
| Silver Top | 4/5 | 80 | 4/9 | 44 | 3/5 | 60 | 5/7 | 71 | 7/8 | 88 | 3/9 | 33 | 0/4 | 0 | 26/43 | 60 |
| Folger | 8/9 | 89 | 2/10 | 20 | 2/10 | 20 | 2/9 | 22 | 5/10 | 50 | 4/9 | 44 | 0/5 | 0 | 23/57 | 40 |
| Japanese Ribbon | 7/10 | 70 | 3/8 | 38 | 3/9 | 33 | 4/10 | 40 | 4/10 | 40 | 0/9 | 0 | 0/5 | 0 | 21/56 | 38 |
| Early Rose | 6/7 | 86 | 1/5 | 20 | 2/7 | 29 | 1/5 | 20 | 5/5 | 100 | 0/7 | 0 | 0/3 | 0 | 15/36 | 42 |

[1] Numerators of the fractions signify the number of infected plants. Denominators signify the number of plants inoculated.

These greenhouse experiments demonstrated the dependence of the fungus on warm and humid weather for vigorous growth. No conclusion could be drawn as to the degree of resistance or non-resistance to the fungus of the different varieties of sorghum. No variety was immune.

*Laboratory Experiments.* Sorghum seeds were germinated in blotters and the fresh, young seedlings transferred to sterile Petri dishes,—five in a dish. In each experiment thirteen dishes of each variety were prepared

—two for each strain of Phoma and one for a check. These were inoculated by spraying with an atomizer a water suspension of conidia. Check plants were sprayed with sterile water. The test was made four times, each time with similar results. The number of days required for pycnidia to develop varied according to weather conditions, but to a lesser degree than in the greenhouse. On these plants the pycnidia developed on roots and stems as well as on the leaves. The following table gives the combined results of three experiments performed under practically the same conditions of temperature and moisture and with readings taken at nearly the same intervals.

TABLE 2

*Seedlings grown in covered glass dishes. Readings taken 29 days after inoculation Average of three laboratory experiments.*

| SORGHUM INOCULATED | NO. OF PLANTS FOR EACH STRAIN OF PHOMA | NUMBER OF PLANTS INFECTED BY STRAINS OF PHOMA FROM | | | | | | CHECK[1] | TOTAL AMT. OF INFECTION BY ALL STRAINS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | PLANTER'S FRIEND | RED X | COLLIER | ORANGE | SAPLING | SO 303 1 | | | % |
| Early Amber | 30 | 14 | 23 | 23 | 13 | 23 | 20 | 0/15 | 119/180 | 66 |
| Silver Top | 30 | 22 | 22 | 18 | 17 | 18 | 18 | 0/15 | 115/180 | 64 |
| Folger | 30 | 16 | 13 | 12 | 12 | 14 | 20 | 0/15 | 87/180 | 48 |
| Japanese Ribbon | 30 | 20 | 19 | 17 | 8 | 12 | 10 | 0/15 | 86/180 | 48 |
| Early Rose | 30 | 21 | 25 | 25 | 19 | 17 | 22 | 0/15 | 129/180 | 72 |

[1] Numerators of fractions signify the number of infected plants. Denominators signify the number of plants inoculated.

All of the varieties of sorghum became infected and all the strains of Phoma produced infection. Of the sorghums, Early Rose seemed the least resistant in these experiments, while Folger and Japanese Ribbon appeared most resistant. The seedlings showed this in a much more striking way than the numbers in the table indicate, Early Rose seedlings always being much more diseased than the Folger and Japanese Ribbon. The strains of Phoma showed differences in the amount of infection they produced in the different varieties of sorghum, but these differences were not uniform in each experiment. All the strains appeared alike as re-

gards their morphology and manner of growth on the different varieties of sorghum plants. It is believed that they are the same fungus found growing on different hosts, and the difference found in the amount of infection produced by them was probably due to their previous life history.

### GERMINATION AND GROWTH OF DISEASED SEED

To determine the effect on germination of the presence of Phoma pycnidia on the sorghum seed, a comparative test was made of diseased and uninfected seed. There were four varieties of sorghum showing pycnidia on the seed coats, used in the test: Orange, Planter's Friend, Red X, and Sapling. Seed showing Phoma pycnidia and seed apparently clean of the fungus, were selected from the seed bags and without treatment of any kind, dropped into sterile Petri dishes on moist blotting paper. As shown in the following table the germination percentage of the infected seed is less than that of the clean. Some of the seed germinated and, later, pycnidia developed on the leaves of some of the resulting seedlings. Some of the seed did not germinate, but in the moist warm atmosphere of the glass dish developed mycelium and new pycnidia. The diseased seed of Planter's Friend produced clean seedlings. Of the checks, a Red X seedling showed pycnidia.

TABLE 3

*Germination of diseased seed in Petri dishes*

| VARIETY OF SORGHUM SEED | INFECTED SEED | | | | HEALTHY SEED | | | |
|---|---|---|---|---|---|---|---|---|
| | NO. OF SEEDS | NO. OF SEED GERMINATED | GERMINATED | INFECTION | NO. OF SEEDS | NO. OF SEED GERMINATED | GERMINATED | INFECTED |
| | | | % | | | | % | |
| Orange | 10 | 7 | 70 | 1 dead seed<br>2 seedlings | 5 | 5 | 100 | 0 |
| Planter's Friend | 10 | 9 | 90 | 0 | 5 | 5 | 100 | 0 |
| Red X | 6 | 3 | 50 | 1 seedling<br>2 dead | 5 | 5 | 100 | 1 seedling |
| Sapling | 10 | 10 | 100 | 1 seedling | 5 | 5 | 100 | 0 |

These results indicate the possibility of spreading the disease by means of infected seed and the loss in the field from the sowing of such seed. After the diseased seeds had germinated and passed safely through the early seedling stages, the fungus did not appear to affect severely the maturing of the sorghum plants. Diseased seeds (Planter's Friend) were germinated in pots in the greenhouse. Those that appeared above

ground grew into healthy looking plants and matured seeds which were found free from pycidnia.

### OTHER PLANTS EXPOSED TO INFECTION OF THE FUNGUS.

The area in the United States in which sweet sorghum is cultivated has spread rapidly in the last few years. It is grown in the central and southern states and is an important crop in Alabama, Arkansas and Florida. In this region grain of forage sorghum, corn and sugar cane are crops of great fiscal importance. For this reason it was a point of some interest to see whether grain sorghum, sugar cane and corn were susceptible to the sweet sorghum Phoma.

*Grain sorghum susceptible to sweet sorghum Phoma.* A grain sorghum of the variety brown durra, named Yellow Jerusalem Corn was infected with two strains of sweet sorghum Phoma: the Phoma found on Red X seed and the Phoma originally found growing on sorghum leaves gathered in Arkansas (So 303 1). The Red X Phoma cultures had been growing for a year in the laboratory and So 303 1 for half a year. The grain sorghum seeds were germinated in blotters, the young seedlings transferred to sterile Petri dishes—five in a dish—and sprayed with water suspensions of conidia. There were 20 seedlings inoculated with each strain of Phoma and 10 check seedlings sprayed with sterile water. In 16 days the set of plants inoculated with Red X Phoma showed 7 seedlings which had developed pycnidia on leaves, stems and roots, while the set inoculated with So 303 1 showed visible infection on 4 seedlings in 18 days. The checks remained free from pycnidia.

*Sugar cane and corn susceptible to the sorghum Phoma.*—Some experiments were made in order to test the pathogenicity of the sorghum Phoma on the leaves of sugar cane and corn.

Four small sugar cane plants of the Louisiana Purple variety were used in the test. They were growing thriftily in pots in the tropical greenhouse. One plant was inoculated with the strain of Phoma taken from Planter's Friend seed, another with the Collier strain, and the third with So 303 1. The fourth plant, held as a check, was sprayed with sterile water. In two weeks pycnidia were found on the lower leaves of the plants sprayed with the Phoma from Planter's Friend and from Collier. The edges of the leaves had yellowed and pycnidia had formed in the dry leaf tissue. The plant inoculated with So 303 1 and the check remained free from the fungus. At the same time a search was made for signs of Phoma on the other sugar cane plants growing in the greenhouse, but no signs of the fungus were found. The infected cane plants were not checked in growth by the Phoma and there was no indication that the

fungus was more than slightly pathogenic to sugar cane. The Phoma fungus on the sugar cane leaves was recovered in the laboratory and was identical with the sorghum Phoma.

In the test made with corn (*Zea mays*) the variety used was U. S. Select 187. The same three strains of Phoma were used that were used in the sugar cane experiment. Two sets of corn seedlings growing in pots in the greenhouse and 2 sets of seedlings growing in glass dishes in the laboratory were used. Six plants were inoculated with each fungus culture and three plants were sprayed with water in each set. In the laboratory the leaves of the corn seedlings inoculated with the Collier strain of Phoma showed pycnidia in two weeks. In a month all three Phoma strains had produced pycnidia on two or more plants. The checks remained free of the fungus. In the greenhouse the seedlings showed no signs of Phoma pycnidia at the end of a month. There was no indication in this test that the sorghum Phoma was more than slightly injurious to the corn plants.

## CROSS INOCULATION OF THE FUNGUS

*Sorghum seedlings inoculated with Phoma from sugar cane.* Folger, Early Rose, Japanese Ribbon, Early Amber, and Silver Top seedlings growing in glass dishes were inoculated with conidia from cultures made from pycnidia growing on sugar cane. This sugar cane had been inoculated with Phoma growing on sorghum seed (Planter's Friend). In two weeks Early Rose, Folger, and Early Amber seedlings showed pycnidia on the leaves, in a month all of the five varieties of sorghum showed infected plants. The checks remained free of Phoma.

*Sorghum seedlings inoculated with Phoma from sorghum.* A test parallel with the sugar cane Phoma was made with a culture of Phoma obtained from Early Rose sorghum which had been inoculated in the greenhouse with the conidia from pycnidia found on Sapling seed. The same five varieties of sorghum seedlings growing in glass dishes were sprayed with conidia. Two weeks afterward pycnidia were found on the leaves of some of the Early Rose, Folger, and Japanese Ribbon plants. In a month seedlings of every variety had become infected. The checks showed no pycnidia.

*Sorghum seeds inoculated with Phoma from sorghum and sugar cane.* Twenty sorghum seeds (Early Amber) of the 1920 harvest were sprayed with Phoma conidia derived from sorghum (Early Rose) which had been inoculated with Phoma taken from sorghum seed (Sapling).

At the same time another set of 20 seeds was sprayed with conidia taken from the sugar cane inoculated in the greenhouse. One half of the seed was scarred with a knife before inoculation, the other half not. The seeds were not sterilized but were kept in sterile Petri dishes. All the

seed germinated and all the scarred ones,—both check and inoculated, were covered with saprophytic fungi. The unscarred seed remained cleaner. In three weeks the seedlings and fungous mycelium had dried out and the mycelium was removed from the seeds with a needle. Pycnidia were found on some of the scarred and some of the unscratched seeds, both inoculated with the sorghum Phoma and with the sugar cane fungus. Examination of infected seed showed that the mycelium had penetrated the outer layer only of the seed coat.

### DESCRIPTION OF THE FUNGUS ON ITS HOST.

*Pycnidia.* When walking through a field of mature sorghum, the Phoma infections were usually found on the edges and tips of the lower leaves of the stalks. The pycnidia were generally found in dry spots on the leaves, either scattered or in groups; often they developed in lines between the veins of the leaves. (Fig. 2.)

FIG 2. PYCNIDIA OF PHOMA INSIDIOSA ON A SORGHUM LEAF.

They were at first covered by the epidermis, but later broke through. Occasionally the developing pycnidia were able to rip off and push up to some extent the cuticle of the tender sorghum seedlings which were growing in the laboratory, before it gave way to the steady pressure of the fruits. They varied greatly in size and shape; some globular, others lens shaped and occasionally compound pycnidia were produced with a single opening or ostiole. The ostiole varied in shape, sometimes it was a pore, the cells surrounding it a darker brown color than the pycnidial wall; on some pycnidia the ostiole was a well developed beak and there were shapes between these extremes. The mature pycnidial wall was dark brown and black when dried out. This variation in form was noticed especially in the pycnidia grown in the greenhouse and in laboratory cultures.

*Mycelium.* No perithecia were seen either on the host plants or in cultures. The mycelium in the tissue of the host plant was scant, even when pycnidia were developing. Sections of infected sorghum leaves showed that as a rule there was but one hypha in a leaf cell. The hypha was constricted when passing through the cell walls. The mycelium was found passing along the vascular bundles in the phloem cells. Cross sections of leaves usually showed the pycnidia developing next to a vein. Mycelium was never seen in the vessels. In the leaf tissue of sorghum seedlings inoculated and growing in Petri dishes, the fungus was found in all the cells except the vessels.

A search was made to see whether any of the hyphae growing from the conidia sprayed on the leaves entered the stomata. In only one case was this phenomenon seen, while in several cases they were observed crossing the stomatal opening. Hyphae have been found entering a break in the leaf epidermis. Whether this break was due to fungus action or to a mechanical accident is not definitely known. In view of the repeated successful inoculations by spraying conidia on uninjured seedlings and of a phenomenon observed in the germinating conidia, it is thought that the hyphae of the germinating conidia possess the power to penetrate the epidermis of the sorghum plant when it is in a tender or weakened condition, and that the fungus invades the host plant in this manner as well as by entering through accidental wounds in the epidermis.

## CULTURAL CHARACTERISTICS OF THE FUNGUS

*Mycelium.* The variability of Phoma in culture makes it difficult to give a satisfactory description of its appearance. Its characteristics, either morphological or physiological, are not well fixed. The mycelium in cultures on agar was usually rather sparse, but by repeated transfers of mycelium a relatively abundant sterile growth could be cultivated. At first the hyphae were white and sparsely septate. After a short time the submerged hyphae became brown and short celled, in certain circumstances and on certain media they became olive-green or pink colored. The aerial mycelium was usually white or grey colored with occasional pink colored clumps. The dark color of the cultures was sometimes caused by colored hyphae, sometimes by the presence of innumerable black pycnidia. When growing on a favorable medium without interference, few or no pycnidia developed. If the hyphal growth was stopped either by cutting out a part of the culture, or by the meeting of growing hyphae of neighboring colonies, a row of pycnidia developed along the cut edge or the border between the colonies. Advantage could be taken of this tendency of the fungus and when fresh pycnidia were wanted quickly, a poured plate was made with thickly sown conidia. The germ-

inating conidia rapidly produced abundant pycnidia and scant mycelium.

*Chlamydospores.* The chlamydospores were variable in size and shape. Their occurrence appeared to bear some relation to available nutriment, as they were usually present when few or no pycnidia were forming. They were both terminal and intercalary. Often the pink colored clumps of aerial mycelium were composed of hyphae with innumerable chlamydospores.

*Effect of light and medium on the mycelium.* A characteristic, soon noticed, of the fungus when growing on cornmeal agar was a pink discoloration of the medium, which the mycelium produced when growing in the light. This was especially marked in poured plates exposed to the light just after germination of the conidia. Each conidium was the center of a pink spot. A steadily-growing Petri dish culture, undisturbed for several days, showed a series of concentric pink and white circles radiating from the conidium. A count showed that the white circles marked the spaces traversed by the hyphae during the night, the pink circles during the day. This pink color faded as the culture aged. Old and slowly growing mycelium did not produce the color. All the strains used in these experiments showed at first this pink discoloration. During the summer months with a mean temperature of 80° F., the life cycle of the fungus was completed in about two days, and the pink color was always found on cornmeal agar when growing in the light. In the autumn scattered colonies were noticed in the plates which produced no discoloration of the medium, but developed pycnidia more quickly and abundantly than the pink colonies. At first it was thought these might be contaminations, then that they were caused by the cool, dry atmosphere in the room which had caused a change in the life processes of the fungus, for now it frequently took a conidium two days to germinate and two weeks to complete its life cycle. A test was made with a single mature pycnidium taken from a Sapling culture two months old. The fruit was crushed and the conidia plated in cornmeal agar in a series of Petri dishes. Half the plates were covered from the light, half exposed. One set of the cultures grew in temperature of 68° to 70° F., the other set in a temperature of 79° to 81° F. Both kinds of colonies developed in all the plates. Experiments showed that all the strains of Phoma developed both kinds of colonies, though in different degree. At one extreme the Red X fungus produced during the winter months innumerable pycnidia on a scant mycelium and no stain on cornmeal agar even when growing in the light (Plate X, fig. 1), while the So 303 1 strain (Plate X, fig. 2), continued to develop the pink staining mycelium even in the dark.—Though cultures were developed from conidia thickly sown and grown in the dark which produced the nonstaining, pycnidia-developing mycelium, even

then occasional pink colonies developed in these plates. Plate X illustrates this difference in the appearance of the cultures. These cultures were plated in cornmeal agar at the same time and kept under the same conditions.

TABLE 4

*The production of color, pycnidia and chlamydospores in cornmeal agar poured plate cultures by Phoma insidiosa obtained from various sources.*

| SOURCE OF CULTURE | PART FROM WHICH CULTURE WAS MADE | FIRST PLATED | COLOR PRODUCED IN AGAR: AT FIRST PLATING | COLOR PRODUCED IN AGAR: OCT. 20' CULTURES, 1½ MOS. OLD | COLOR PRODUCED IN AGAR: Feb. 1921, 3 MO. OLD | COLOR PRODUCED IN AGAR: Feb. 1921, 1 YR. OLD | PYCNIDIA | CHLAMYDOSPORES |
|---|---|---|---|---|---|---|---|---|
| Planter's Friend | Seed coat (1919 seed) | Feb. '20 | Pink | No color | | No color[1] Pink | Numerous | Present |
| Red X | " | Feb. '20 | " | " | No color | No color[1] Pink | " | " |
| So 303 I | Early Amber leaves inoc. with So 303 | Aug. '20 | " | Pink | Pink | .... | Less numer- | " |
| Sapling | Seed Coat (1919 seed) | Aug. '20 | " | No color | No color[2] pink | .... .... | Numerous | " |
| Orange | " | Aug. '20 | " | " | .... | .... | " | Not examined |
| Collier | " | Aug. '20 | " | " | .... | .... | " | Not examined |
| McLean | " | Feb. '21 | " | .... | .... | .... | " | Present |

[1] Two kinds of colonies, one producing pink and one no color. (See plate X.)

[2] A fresh culture from a 1919 seed coat planted in Feb., 1921, fruited sparsely after three weeks. The conidia from this fresh culture developed two kinds of colonies, one producing a pink stain on agar and one no color.

The fungus seemed to show a tendency to a summer and a winter phase of growth. In the summer phase the fungus developed a mycelium which was sensitive to the light, while in winter it developed innumerable pycnidia on a scant mycelium insensitive to light.

The brilliancy of the stain which developed, varied with the medium. The deepest color appeared in dextrose beef agar, where the hyphae also were colored a deep red. Next in vividness was the beef juice agar, oatmeal agar, dextrose litmus agar and oxalic acid beef juice agar. So 303

1 cultures on potato cylinders developed a white mycelium from which oozed drops of red liquid. The red coloring matter in the hyphae and the agar was partly soluble in alcohol.

*Conidia.* The conidia were hyaline, one-celled. Young conidia, when freshly ejected from the pycnidium, appeared to be filled with solid protoplasm, later two, rarely three, globules formed. Mature conidia usually showed two globules when ejected. In shape they were sub-cylindrical, with blunt sometimes tapering ends. (Fig. 3.)

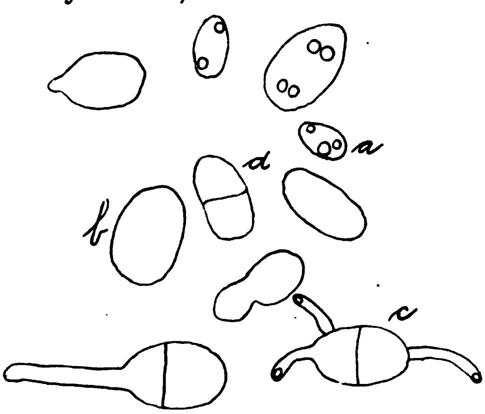



FIG. 3 CONIDIA OF PHOMA INSIDIOSA GERMINATED IN WAER. X 625.

The germination of the conidia was observed in Van Tieghem cells. The conidias welled to about three times their original size before the germinating hyphae protruded. (Fig. 3 b.) One or two hyphae appeared, usually at the ends of the conidium, but sometimes at the sides. (Fig. 3, c) Frequently a cross well developed in the conidium before the germinating hypha was produced. (Fig. 3, d.) The conidia germinated readily in distilled water, but growth ceased soon after germination. The growing tip of the germinating hypha was always dense with protoplasm and highly refractive when observed through the microscope. In the water cultures a phenomenon was observed which was thought of significance with regard to the penetration of the epidermal cells of the sorghum leaf by the fungus. The tips of the germinating hyphae of those conidia lying next to the cover glass fastened themselves to it for a short period of time. The tips rounded themselves against the glass as though using suction and in the center a dense, shining, round spot of protoplasm was observed. (Fig. 3, c.)

Pycnidia and condia varied in size. The following table shows the mean measurements of fruits and spores taken from different sub-strata.

## TAXONOMY

For the present the writers regard the Phoma gathered from the different varieties of sweet sorghum seeds and leaves as the same fungus. The cultures arising from these different sources have been kept carefully separated, in order that variations in the different strains as regards morphology and manner of growth on the different sorghums,

TABLE 5

*Measurements in microns of pycnidia and conidia on seeds, leaves and in cultures*

| SOURCE | PYCOIDA | | | CONIDIA | | |
|---|---|---|---|---|---|---|
| | NO MEASURED | RANGE IN μ | MEAN SIZE IN μ | NO MEASURED | RANGE IN μ | MEAN SIZE IN |
| Planters' Friend—Seed coat | 10 | 98 to 252 | 159 | 10 | 2.6 to 3.5 × 5.3 to 7.0 | 3.3 × 6.6 |
| G.ume | 10 | 45 " 108 | 70 | | | |
| Leaf—(Greenhouse inocu.ation to Early Amber.) | 5 | 45 " 99 | 76 | | | |
| In culture (cornmeal agar) | 10 | 81 to 185 | 143 | 10 | 2.6 to 3.5 × 4.4 to 7.0 | 3.3 × 5.0 |
| So 303—Leaf—Field infection | 20 | 56 " 168 | 107 | 20 | 2.7 " 4.4 × 6.5 " 8.8 | 3.5 × 6.3 |
| So 303 1—Laboratory inoculation to Ear.y Amber | 4 | 90 " 162 | 124 | 10 | 1.4 " 3.2 × 3.8 " 7.8 | 2.7 × 6.0 |
| Leaf—Laboratory inoculation to Brown Durra | 10 | 36 " 90 | 53 | 10 | 3.5 " 4.4 × 4.4 " 7.0 | 3.6 × 5.6 |
| In culture (cornmeal agar) | 10 | 45 " 90 | 67 | 10 | 1.8 " 3.5 × 4.4 " 7.0 | 3.0 × 5.3 |
| So 303 1 to Brown Durra—In culture (cornmeal agar) | 10 | 41 " 126 | 59 | 10 | 2.6 " 3.5 × 4.4 " 7.0 | 3.2 × 5.5 |
| Red X—Leaf—Laboratory inoculation to Brown Durra | 10 | 45 " 90 | 66 | 10 | 3.5 " 3.9 × 5.2 " 7.0 | 3.5 × 6.3 |
| In culture (cornmeal agar) | 10 | 54 " 99 | 80 | 10 | 2.6 " 3.9 × 5.0 " 7.9 | 3.5 × 6.7 |
| Red X to Brown Durra—In culture (cornmeal agar) | 10 | 45 " 90 | 64 | 10 | " 3.5 × 5.0 " 7.9 | 3.5 × 6.5 |
| Sapling—Leaf—Greenhouse inoculation to Early Rose | 6 | 41 " 117 | 73 | | | |
| In culture (cornmeal agar) | 32 | 41 " 224 | 169 | 10 | 2.6 " 3.9 × 4.4 " 6.1 | 3.5 × 5.3 |
| Orange—In culture (cornmeal agar) | 11 | 27 " 144 | 79 | | | |
| Collier—Leaf—Laboratory inoculation to Early Rose | 10 | 27 " 16 | 89 | | | |
| Silver Top—Lemma | 10 | 72 " 171 | 142 | | | |
| Albaugh Early—Seed coat | 10 | 84 " 168 | 132 | | | |
| McLean—In culture (cornmeal agar) | 10 | 81 " 162 | 122 | 10 | 2.6 to 4.4 × 4.4 to 7.0 | 3.5 × 5.6 |
| Mean | 248 | 27 to 16 | 012 | 130 | 1.4 to 4.4 × 3.5 to 8.8 | 3.4 × 5.9 |

cane, corn, grass and on artificial media might be noticed. Such variations as have been found have been described. They are not thought to be sufficient to warrant special naming of the strains.

The first published report of Phoma on sorghum seed, which could be found was that by F. Tassi in the Bulletino del LaboratorioBotanico della R. Universiti di Siena, Vol. 1, p. 8, 1897.

*Phoma insidiosa* F. Tass.

"Maculis cinereo-albicantibus epidermidem seminum late ambientibus: peritheciis sparsis, vel sub-gregariis, piceis, immersis, primo epidermide tenuissima sub-velatis, ostiolo late pertusis, 70–80 μ diam.; sporulis innumeris, ellipticis initio continuis, tarde minute 2-guttulatis, vel granulosis, hyalinis, 6 × 2–2½ μ. (Tab. IX, fig. 8.)

Hab. in seminibus *Sorghi vulgaris* B. *Dourah* ex Abyssinia (1897)."

*Phoma insidiosa* F. Tass.

Spots ash colored to somewhat white spreading over the epidermis of seeds; pycnidia sparse or somewhat grouped, black, immersed, at first somewhat covered by the epidermis, ostiole somewhat protrudent, 70–80 μ diameter, innumerable spores, elliptical, at first continuous, later two minute globules, or granular, hyaline, 6 × 2–2½ μ.

Collected on seed of *Sorghum vulgaris* B. durra, in Abyssinia 1897.

Tassi found *Phoma insidiosa* growing on durra sorghum seed. The American fungus was first seen on sweet sorghum seed and leaves, and only later found on grain sorghum leaves. But as brown durra sorghum seedlings were infected by the sweet sorghum Phoma, as well as sugar cane and maize seedlings, it was thought the description of *Phoma insidiosa* corresponded sufficiently to apply to the American fungus. The mean measurement of the diameter of the American pycnidia is larger, but the Tassi measurements fall within the extreme measurements. The conidia of the American fungus also are larger, but as some of them measured 6 × 2.7 μ, these measurements were not deemed sufficiently greater to warrant giving the fungus another name. The name *Phoma insidiosa* Tassi is, therefore, tentatively given the fungus described in this paper, until a type specimen of the African fungus has been examined.

### VITALTY OF PHOMA IN NATURE AND IN CULTURES

The Phoma found on sweet sorghum leaves collected in 1917 and 1918 and kept in the laboratory was dead when tested in November, 1920. Examination showed that most of the pycnidia ontained no spores. The few found did not germinate when tested.

Conidia taken from pynidia found on sorghum seed readily germinat-

ed and developed fruits for a year after harvest. The cultures used in many of the experiments were started in August 1920 from diseased seed harvested in 1919. By January 1921, however, the fungus on the seed showed a decided decrease in vitality. Very few conidia would germinate and those which grew produced mycelium and few pycnidia.

Conidia were still viable after thirteen months of desiccation in Petri dish cultures.

Little definite information can be given as to the economic importance of the sorghum Phoma. It evidently is widespread in occurrence in sorghum growing regions and appears persistently year after year. It is a facultative parasitic fungus as shown by its presence on all parts of the shoot of the sweet sorghum plant from the seedling stage to maturity and its ability to infect sugar cane, corn and grain sorghum. After watching the fungus's great adaptability as demonstrated in culture, the senior writer believes a search among the wild grasses growing in the sorghum territory will show the fungus growing on a number of them.

Mr. H. B. Cowgill, reports there was "difficulty in obtaining a stand of the sweet sorghums, especially in the early spring, on the experimental plots at South Fort Smith, Arkansas. Each season since the inception of this work there in 1918, certain varieties appear more or less susceptible to an apparent 'damping-off' following cool, wet weather. The five varieties of sweet sorghum grown extensively in the vicinity show relative susceptibility to the damping-off of the seedlings in the following order: Red X, Coleman, Indiana Amber, Folger's Early and Japanese Ribbon."

## SUMMARY

Phoma infected sorghum has been collected in the different sorghum-growing states during the last five years.

The fungus has been found on the leaves of seedlings and the leaves, seed heads and seed of mature sweet sorghum plants.

It remains viable on seed for a year. The vitality is poor at the end of two years.

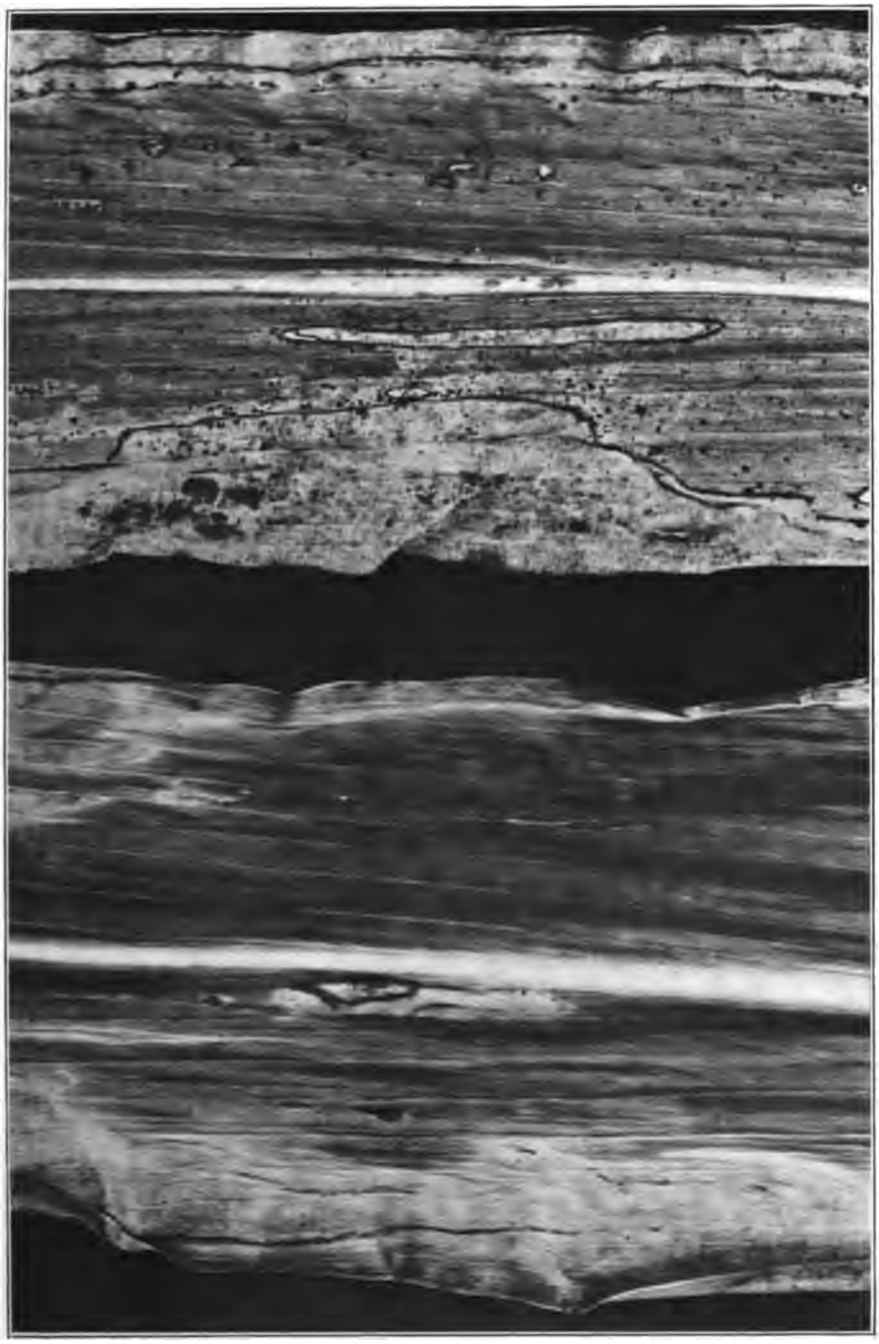
It has not been found viable on dry infected leaves two years old.

Of the eleven varieties of sorghum examined and experimented with, no variety has been found which is immune from the fungus.

The fungus can grow on the leaves and stems of the seedlings of the forage sorghum, Brown Durra.

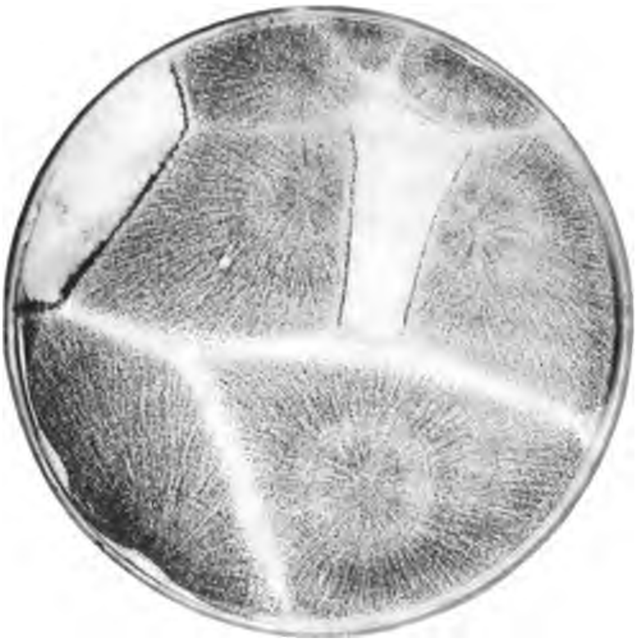
It can also grow on sugar cane and corn seedlings, but is of slight pathogenicity.

SUGAR PLANT INVESTIGATIONS
BUREAU OF PLANT INDUSTRY,
U. S. DEPARTMENT OF AGRICULTURE.



PHOMA LESIONS ON SORGHUM LEAVES

Upper leaf: lesion with indefinite outline on variety Silver Top.
Lower leaf: lesion with definite dark outline on variety Early Amber.



PETRI DISH CULTURES OF PHOMA INSIDIOSA

Fig. A. Culture from sorghum variety Red X producing innumerable pycnidia and no stain in corn meal agar.

Fig. B. Culture from sorghum So 303 I producing pink stain and few pycnidia in corn meal agar.

PYCNIDIA OF PHOMA INSIDIOSA ON SEEDS OF SORGHUM
VARIETY PLANTER'S FRIEND.

# THE RELATION OF SPORE LOAD TO THE PER CENT OF STINKING SMUT APPEARING IN THE CROP.

F. D. HEALD

## INTRODUCTION

The value of the quantitative estimation of the number of smut spores carried by seed wheat was first pointed out by Bolley[1] in 1897, and this was given further consideration by Cobb[2] in 1904 and 1905. Although the centrifuge and counting cell have been used for determining the presence or absence of spores of disease producing fungi on seed, the direct relation of the spore load carried by each individual grain of wheat to the amount of smut appearing in the crop seems to have received but little attention. Cobb in 1904 wrote as follows: "The amount of smut that can be tolerated can only be determined by sowing through a series of seasons quantitatively examined seed presenting the necessary degrees of infection, and subsequently examining the resulting crops . . . I would call the attention of experiments to the absence at the present time of any such data."

The determination of the spore load can be of direct value to the farmer, first, as a guide in the selection of wheat for seed purposes, and second so that he may know whether seed treatment is necessary or will be a paying procedure.

There is never any doubt that visibly smutted seed is carrying large numbers of smut spores attached to each individual grain, but it is also known that apparently clean seed may be carrying large numbers of spores. A quantitative microscopic analysis can determine which of several apparently smut-free samples contains the smallest number of spores, and this knowledge could be used by a farmer to good advantage in the selection of his seed. On the basis of present information the sample showing the least smut would naturally receive first choice, but we should be forced to recommend seed treatment for all except smut-free seed. If however, we have available data showing the relation of the spore load to the amount of smut appearing in the crop, it should be possble to predict with reasonable accuracy the approximate per cent of

[1]Bolley, H. L. The use of the centrifuge in diagnosing plant diseases. Proc. Soc. for the Prom. of Agr. Science **23**: 82–85. 1902.

[2]Cobb, N. A. Quantitative estimation of disease spores. Agr. Gaz. New South Wales **15**: 670—680. 1904.

——— Quantitative estimation of bunt in seed-wheat. Agr. Gaz. New South Wales **16**: 1113–1117. 1905.

smut that would appear in any crop provided seed disinfection is not practiced.

Considering the enormous acreage of wheat we can be reasonably certain that much seed wheat is disinfected needlessly. This not only involves the cost of seed disinfection which reaches a high figure each year, but seed treatments cause very pronounced reductions in germination, giving poor stands or requiring the use of larger amounts of seed. Seed treatment, in the absence of definite information, has been regarded as "an insurance" or a "playing safe," but with microscopic analyses and field data to back them, it can be put upon a more scientific basis.

The present paper will present some of the results which have been obtained during the last few years in our study of the bunt (Tilletia tritici) problem in the Pacific Northwest, so far as they are related to the spore-load.

### THE NUMBER OF SPORES PER GRAIN

The maximum per cent of smut found in any fields under farm operation during the past six years has not exceeded 88. It is needless to say say that with 88 per cent of all the heads smutted, the grain from such a field would be carrying about the maximum load of smut. In this extreme case each individual grain might be carrying 50,000 to 150,000 spores, but the actual number will depend in part upon the extent to which the smut balls break during the threshing operation. In this connection it may be noted that a single smut ball contains millions of spores. In one analysis Cobb estimated the spore content of a smut ball as 8,000,000. Numerous analyses made of small and large smut balls collected in the vicinity of Pullman have shown 6,000,000 to 9,000,000 spores. The spore-load shown by field samples may vary from the maximum given above to only a few spores per grain, or in certain sections the wheat has been found to be practically smut-free.

### RELATION OF THE WEIGHT OF SMUT USED TO THE PER CENT OF SMUT APPEARING IN THE CROP

In our first studies of spore-load, the amount of smut used was determined by weight using 0.01 to 3 or 4 grams per 100 grams of seed. The smutting was accomplished by adding the given weights of pulverized smut or smut dust to the wheat samples and shaking the seed and smut in a bottle so as to secure as nearly as possible a uniform distribution of the spores over the surface of the grain.

The smut used in our tests has been stored in a cool dry room or in the grain room, in bundles collected at harvest time. Just before using, the smutted heads were ground with an Enterprise food chopper and the chaff

sifted out. In all infection tests smut from the previous harvest has been used, so as to secure maximum germination.

In these first tests no analyses were made to determine the number of spores carried by each grain of wheat. From table 1 it may be noted that 0.5–3 grams was required to produce maximum smutting. From these results it seems evident that Kirchner,[1] who used one gram of smut

TABLE 1

*howing relation of weight of smut per 100 grams of seed to per cent. of smut in the crop*

| WEIGHT OF SMUT PER 100 GRAMS OF WHEAT | PER CENT. OF PLANTS SMUTTED | PER CENT. OF HEADS SMUTTED |
|---|---|---|
| **EARLY WILBUR, SEEDED APRIL 15, 1915** | | |
| None | 0.2 | 0.2 |
| 0.01 grams | 0.6 | 0.3 |
| 0.1 " | 4.3 | 1.6 |
| 0.25 " | 5.4 | 2.4 |
| 0.5 " | 17.5 | 8.5 |
| 1.0 " | 28.1 | 15.4 |
| 2.0 " | 17.5 | 8.5 |
| 3.0 " | 36.9 | 23.5 |
| **EARLY WILBUR, SEEDED APRIL 22, 1916** | | |
| 0.5 grams | | 65.7 |
| 1.25 " | | 73.0 |
| 4.00 " | | 81.9 |
| **EARLY WILBUR, SEEDED MAY 1, 1916.** | | |
| 0.5 gram, | | 9.95 |
| 1.25 " | | 65.82 |
| 4.00 " | | 77.98 |
| **HYBRID 143, SEEDED OCT., 1916** | | |
| 0 grams | | 9.2 |
| 0.01 " | | 18.0 |
| 0.1 " | | 31.1 |
| 0.5 " | | 55.5 |
| 1.0 " | | 55.9 |
| 2.0 " | | 34.2 |

[1]Kirchner, O. Uber die Empfänglichkeit vershiedener Weizensorten für Steinrankheit. Frühlings' Landw. Zeitung 56: 781—794.

to 15 grams of seed in testing the comparative resistance of wheat varieties to smut, used much more smut than was necessary to secure maximum infection.

### THE RELATION OF SPORE LOAD OF NATURALLY SMUTTED SEED TO THE PERCENT OF SMUT IN THE CROP.

In the fall of 1917 a number of farm samples of Bluestem and Marquis wheat were obtained and kept through the winter in cool storage as near comparable to farm conditions as possible. Analyses were made to determine the average number of smut spores per grain of wheat and duplicate plantings were made on both north and south slopes.

The method of making the spore counts was the one that has been employed in all of the later analyses. Since it differs somewhat from the centrifuge methods described by Bolley and by Cobb, a brief description will be presented.

TABLE 2

*Showing relation of spore load of untreated naturally smutted farm seed to the per cent. of smut in the crop*

PLANTED 3-30-18

| SAMPLE NUMBER | VARIETY | NO. OF SPORES PER GRAIN OF WHEAT | PER CENT. OF SMUTTED PLANTS | |
|---|---|---|---|---|
| | | | SOUTH SLOPE | NORTH SLOPE |
| A 1 | Bluestem | 1015 | 1.29 | 1.29 |
| A 2 | " | 562 | 3.63 | 7.42 |
| A 3 | " | 47 | 3.17 | 8.99 |
| A 4 | " | 15 | 0 | 0.43 |
| A 5 | " | 141 | 2.45 | 8.61 |
| A 6 | " | 31 | 0.51 | 0.60 |
| B 1 | Marquis | 23 | 0 | 0.45 |
| B 2 | " | 200 | 0.50 | 1.94 |
| B 3 | " | 468 | 0.63 | 0 |
| B 4 | " | 62 | 0 | 0 |
| B 5 | " | 78 | 0 | 0 |
| B 6 | " | 23 | 0 | 0 |
| B 7 | " | 117 | 0.92 | 0 |
| B 8 | " | 190 | 0 | 0.62 |
| B 9 | " | 8 | 0 | 0 |
| B 10 | " | 8 | 0.61 | 0 |
| B 11 | " | 8 | 0 | 0 |
| B 12 | " | 32 | 0 | 0 |

1. Count out 300 whole grains of wheat.
2. Put into 100 cc. of spore-free water in an Erlenmeyer flask.
3. Shake frequently for one-half hour.
4. Using the Levy counting cell and mechanical stage, make 5 spore counts, using the average number of spores as the spore content of the unit volume of the cell $\frac{2}{5}$cu. millimeter).
5. Compute the average number of spores carried by each grain of wheat.

This method was compared with the centrifuge method and was found to be equally accurate, hence it was adopted for general use since it was less troublesome.

The results obtained for the 1918 plantings are shown in table 2. Simmilar analyses and planting tests were made in the Spring of 1920 using a large number of varieties as shown in table 3.

TABLE 3

*Showing the relation of the spore load of naturally smutted, untreated farm seed to the per cent. of smut in the crop*

PLANTED SPRING, 1920

| | NO. OF SEED LOTS | NO. OF SPORES PER GRAIN | PER CENT. SMUTTED PLANTS | |
|---|---|---|---|---|
| | | | NORTH SLOPE | SOUTH SLOPE |
| Marquis | 1 | 0 | 0 | 0 |
| " | 4 | 18–83 | 0 | 0 |
| " | 8 | 208–374 | 0 | 0 |
| " | 3 | 478–842 | 1.0 (478) | 0 |
| Early Baart | 6 | 0 | 0 | 0 |
| " " | 2 | 84–156 | 0 | 0 |
| " " | 1 | 47 | 1.87 | 0 |
| " " | 1 | 508 | 0 | 0 |
| " " | 1 | 2339 | 1.96 | 1.01 |
| Hybrid 143 | 1 | 87 | 0 | 0 |
| " 143 | 1 | 645 | 0 | 0 |
| " 143 | 1 | 1185 | 2.00 | 1.35 |
| " 143 | 1 | 4180 | 5.49 | 2.00 |
| " 143 | 1 | 43.78 | 2.52 | 2.00 |
| " 143 | 1 | 8188 | 0 | 2.00 |
| Jenkins Club | 1 | 779 | 1.05 | 0 |
| " | 1 | 1070 | 2.22 | 0 |
| " | 1 | 6087 | 0 | 0 |
| " | 1 | 9505 | 2.52 | 1.74 |
| " | 1 | 12167 | 3.00 | 2.00 |
| Blue stem | 4 | 176–1320 | 0–1.43 | 0–1.00 |
| Red chaff | 4 | 364–852 | 0–1.43 | 0–0.88 |

Since the amount of smut shown in spring wheat under ordinary farm conditions has been rather low, especially during the last few years, it is not surprising that seed samples taken at random would give rather low spore counts. The samples varied from those smut-free to those showing a maximum of 12167 spores per grain. In these samples, those which were smut-free, produced no smut in the field plantings, while some showing an evident spore-load, also remained smut-free in the planting test. In general however we can note a relation between the number of smut spores carried by the seed and the per cent of smut appearing in the crop. No uniformity could be expected by comparing a series of samples collected at widely different points on account of the diverse conditions to which the grain may have been subjected prior to being assembled for our tests. With but few exceptions the plantings on the north slopes always gave a higher per cent of smut than plantings on the south slope.

By making use of the seed from a series of experimental plots used for another purpose it was possible to obtain very heavily smutted seed of Hybrid 143 and Jones' Winter Fife. The fields of Hybrid 143 which furnished the naturally smutted seed showed 4.83 to 94.91 per cent of the heads smutted, while the Winter Fife plots showed 0.49 to 82.36 per cent of all the heads smutted. The 10 lots of wheat threshed from each variety therefore showed a wide range of spore-loads.

In order to overcome the possible error from smut infections from spores in the soil, the plats selected for the planting test was covered with a layer of straw 4 to 6 inches thick and then fired. The ground was then raked and the seed planted at once. Previous experience had shown that this treatment was sufficient to kill the wind-blown smut that might have been present in the surface layers of the soil. A duplicate planting of the Hybrid 143 was made in the spring. The results are shown in tables 4 and 5. The relation between spore-load and per cent of smut in the crop does not seem to be as regular and proportional as might be expected, but with some fluctuations there is a gradual increase in the per cent of smut with increase in the number of spores carried by each grain. Even the seed lots showing the highest spore-load did not produce maximum smutting. It seems rather difficult to understand why a spore-load of 40,000 spores per grain should but little more than double the amount of smut produced by a spore-load of 4500. Why will a spore-load of a thousand or more spores per grain not produce maximum smutting? Theoretically it would seem that such a behavior shold be true.

### THE RELATION OF SPORE LOAD OF ARTIFICIALLY SMUTTED WHEAT TO THE PER CENT OF SMUT IN THE CROP

Since it was not possible to work with a large number of varieties, a

TABLE 4

*Showing the relation of spore load of naturally smutted untreated Jones Winter Fife to the per cent. of smut in the crop*

| LOT NO. | PER CENT. OF SMUT HEADS IN CROP FURNISHING THE SEED | NUMBER OF SPORES PER GRAIN | PER CENT. SMUTTED PLANTS |
|---|---|---|---|
| 1 | 8.10 | 833 | 23.66 |
| 2 | 5.16 | 937 | 17.01 |
| 3 | 12.35 | 3437 | 23.21 |
| 4 | 17.66 | 4583 | 31.61 |
| 5 | 0.49 | 937 | 10.40 |
| 6 | 2.20 | 833 | 12.95 |
| 7 | 2.43 | 416 | 8.87 |
| 8 | 0.69 | 625 | 12.21 |
| 9 | 82.05 | 40104 | 70.5 |
| 10 | 82.36 | 45416 | 73.04 |
| 11 | Control, no smut | 0 | 0 |

very resistant variety Marquise, and a very susceptible variety, Jenkins' Club, were selected for test in our spring plantings. The smutting was accomplished in the same manner as noted for the earlier studies on spore-load according to weight, except in the case of the smaller weights of smut. For these, in order to insure an equal distribution of the spores over the seed, the smut was suspended in water and sprayed onto the seed with an atomizer. The results are shown in table 6.

With but little fluctuation the results show a gradual increase in the per cent of smut in the crop with the increase in the spore-load, up to an amount (0.5 gram or about 35000 spores) necessary to produce maximum smutting. The comparison of the results with Marquis and Jenkins' Club brings out a number of interesting features. It is worthy of note that Marquis remained smutfree with 104 to 542 spores per grain, while Jenkins Club produced up to nearly 10 per cent of smutted plants with nearly similar spore-loads. In Jenkins' Club, for example, a spore-load of 5333 spores produced 60.79 per cent of smut while increasing the spore-load to 20687 spores per grain only increased the per cent of smutted plants to 66.23.

A comparison of the results from artificially smutted seed with the results of farm smutted seed as shown in tables 2 and 3, indicate that similar spore-loads do not give similar per cents of smut, but the per cent of smut appearing in the crop is much smaller in the farm infected seed than would be obtained from similar spore-loads of artificially infected seed. This is probably explained by the lessened viability of the spores

which have passed through the winter period on the surface of the seed, over those which have passed the winter in unbroken smut balls. In the artificial smutting the seed was smutted a short time before planting, using newly ground or pulverized smut.

TABLE 5

*Showing the relation of the spore load of naturally smutted, untreated Hybrid 143 wheat to the per cent. of smut in the crop*

| LOT NUMBER | PER CENT. OF SMUT HEADS IN CROP FURNISHING THE SEED | NUMBER OF SPORES PER GRAIN | PER CENT. OF SMUTTED PLANTS | |
|---|---|---|---|---|
| | | | FALL SEEDED | SPRING SEEDED |
| 1 | 78.10 | 24062 | 71.11 | 69.93 |
| 2 | 32.87 | 4271 | 47.10 | 26.80 |
| 3 | 54.17 | 4166 | 64.79 | 57.75 |
| 4 | 4.83 | 2396 | 33.82 | 21.05 |
| 5 | 61.10 | 17187 | 69.86 | 40.57 |
| 6 | 36.41 | 4687 | 41.76 | 23.88 |
| 7 | 38.13 | 8208 | 66.18 | 45.29 |
| 8 | 16.39 | 3229 | 32.20 | 27.53 |
| 9 | 94.91 | 38333 | 65.82 | 72.18 |
| 10 | 93.24 | ? | 69.63 | 73.25 |
| 11 | 0 | 0 | 0 | 0 |

It seems to have been the general opinion of plant pathologists that infection of a wheat plant with bunt might be accomplished from a single spore, but our results seen opposed to such an idea. Food for thought shold be found in the fact that a considerable number of spores per grain, may not be sufficient to cause any infection. At present two possible explanations may be suggested. Either what we may term a multiple infection occurs, that is, an infection in which a number of spores participate, or there is a chemical mass effect due to numbers of spores, and infection may then be from a single infection thread.

## SUMMARY

1. Single smut balls of *Tilletia tritici* contain from 6-9 million spores.

2. The number of smut spores carried by a single grain of normal wheat is designated as its spore-load.

3. The spore-load of wheat due to smutting during the threshing operation has varied from 0 to a maximum of 45416 in the various tests. Smut-free wheat is rare except from the drier sections of the state.

4. In artificial smutting at least 0.5 gram of powdered smut well distributed to each 100 grams of seed is necessary to produce maximum smutting. An increase in weight of smut used up to three grams per

hundred of seed has in some cases slightly increased the per cent of smut appearing in the crop.

5. The use of the Levy counting cell alone has given as satisfactory determinations of the spore-load as the centrifuge and counting cell combined.

TABLE 6

*Showing the relation of the spore load of artificially smutted, untreated spring wheat to the per cent. of smut in the crop*

MARQUIS

| WEIGHT OF SMUT PER 100 GRAMS WHEAT | NUMBER OF SPORES PER GRAIN | PER CENT. OF SMUTTED PLANTS | PER CENT OF SMUTTED HEADS |
|---|---|---|---|
| 0.00 grams | 104 | 0 | 0 |
| 0.005 " | 333 | 0 | 0 |
| 0.01 " | 542 | 0 | 0 |
| 0.1 " | 5043 | 7.31 | 1.79 |
| 0.25 " | 19687 | 15.21 | 2.88 |
| 0.5 " | 34937 | 1.02 | 0.29 |
| 1.0 " | 59229 | 24.81 | 8.22 |
| 2.0 " | 96958 | 56.32 | 16.43 |
| 3.0 " | 183375 | 15.49 | 8.74 |

JENKINS' CLUB

| WEIGHT OF SMUT PER 100 GRAMS WHEAT | NUMBER OF SPORES PER GRAIN | PER CENT. OF SMUTTED PLANTS | PER CENT OF SMUTTED HEADS |
|---|---|---|---|
| 0.0 grams | 104 | 0.49 | 1.80 |
| 0.005 " | 458 | 3.63 | 2.45 |
| 0.01 " | 533 | 9.52 | 5.99 |
| 0.1 " | 5333 | 60.79 | 32.80 |
| 0.25 " | 20687 | 66.23 | 43.77 |
| 0.5 " | 36770 | 90.82 | 84.65 |
| 1.0 " | 65229 | 94.43 | 92.92 |
| 2.0 " | 163971 | 93.38 | 92.55 |
| 3 0 " | 164208 | 98.88 | 94.58 |

6. In artificial smutting a spore-load of 36,000–150,000 has been required to produce the maximum per cent of smut in the crop.

7. The per cent of smut appearing in the crop increases with the spore-load but less rapidly.

8. The per cent of smut appearing in naturally smutted spring wheat is less than would be indicated by the spore-load as based on plantings of artificially smutted samples.

9. Planting tests of samples of spring wheat with known spore-load have made it possible to estimate the approximate amount of smut that will appear in a crop if the seed is planted without disinfection. This does not apply towinter wheat in the Palouse country since soil contamination is general and variable there.

10. With small spore-loads, certain varieties of spring wheat have remained smut-free, while others have given such a low per cent of smut as to make seed disinfection of doubtful value. Our tests of Marquis indicate that this variety will rarely require seed treatment.

11. The spore-load that will produce an appreciable amount of smut (9.52) in a susceptible variety (Jenkins' Club) has given a smut-free crop in a resistant variety (Marquis).

12. The relation of spore-load to the per cent of smut appearing in the crop indicate either that a multiple infection occurs or that there is a chemical mass effect due to numbers of spores.

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# THE DECAY OF SWEET POTATOES (IPOMOEA BATATAS) PRODUCED BY DIFFERENT SPECIES OF RHIZOPUS

L. L. HARTER, J. L. WEIMER, and J. I. LAURITZEN

## INTRODUCTION

A decay of sweet potatoes commonly referred to as soft rot has been attributed by a number of investigators to *Rhizopus nigricans*. The first known report of its occurrence on this crop was made by Halsted (5) in 1890, and since then this organism has been cited as the cause of the decay of a number of other vegetables as well as fruits. Most of the important literature dealing with the decay caused by *R. nigricans* has been previously reviewed by Harter, Weimer and Adams (8) and Stevens and Wilcox (11); hence only some of the crops attacked will be mentioned. They are as follows: tomatoes (*Lycopersicon esculentum*), (2, p., 515-516, 7, 12), potatoes (*Solanum tuberosum*) (9), quince (*Cydonia*) (6), pears (*Pyrus*), raspberries (*Rubus*), currants (*Ribes*), plums (*Prunus*) (2, p. 515-516.) fruits of *Cornus masculus*, *Morus alba* and apple (*Pyrus malus*) (4), figs (*Ficus*) (3), strawberries (*Fragaria*) (10), and red raspberries (11). More recent investigations (1) have shown *Rhizopus nigricans* to be the cause of considerable damage to corn on the seed germinator.

The above references to the literature are su icient to show that *Rhizopus nigricans* is regarded by many investigators as a common cause of the decay of a number of fruits and vegetables. That other species of the genus Rhizopus have not been found to cause decay may be due perhaps in part at least to the facts, first, that *R. nigricans* is probably by far the most common of the parasitic species and, second, to the too common error of classifying all such molds as *Rhizopus nigricans*, without attempting to identify them by comparing with the other species of the genus. Judging from the reports of its isolation from vegetables decayed both in storage houses and on the markets, it is probable that *Rhizopus nigricans* is responsible for more decay than any of the other species. On the other hand, it will be shown that several other members of the genus will rot sweet potatoes. In fact, some of the species which are even more vigorous parasites under artificial conditions than *Rhizopus nigricans* frequently are found, when the isolations are made from fruits and vegetables which are decayed at temperatures above or below the optimum for *Rhizopus nigricans*.

The results of the experiments which are recorded in this paper were derived from a series of inoculations made upon the Yellow Jersey variety of sweet potato with 11 different species of Rhizopus.

### METHODS OF TESTING PARASITISM

Harter, Weimer and Adams (8) have shown that infection seldom results when the spores and hyphae of Rhizopus are smeared on the wounded surface of sweet potatoes, confined in a moist chamber. Furthermore, negative results were usually obtained even when the spores were suspended in water in a "well" made in the potato. If on the other hand a 24 to 48 hour growth of the fungus on sweet potato decoction was poured into a "well" made in the potato and the "well" sealed over with a cover slip set in vaseline or plugged with cotton a large percentage of the potatoes decayed. Since this method is the only one which could be relied upon to give anything like uniform results in moist chambers it has been employed in all these experiments. After inoculation the potatoes were incubated at a temperature suitable for the growth of the particular species of Rhizopus with which the inoculations were made. In this connection it should be pointed out that no attempt was made to incubate the potatoes at the exact optimum temperature for growth for the species of Rhizopus under investigation. Similarly to Hanzawa (7) we found that the species studied could be roughly divided into three groups with respect to temperature; i. e., high, medium, and low temperature forms. There is a considerable range of temperature at which the different species of a single group will thrive well. For example, the high temperature forms grow fairly well at temperatures ranging from 30 to 40° C., and some species have a maximum even higher than 40° C. The medium temperature forms grow best at temperatures varying from 20 to 35° C. and the low temperature forms from 15° to 20° C. It will be seen that there is some overlapping, the lowest range given for the high temperature forms being somewhat less than the highest range for the intermediate forms. It should not be inferred, however, that the different species will not grow at a temperature above or below the range given for the group in which they have been placed. Any of the species will survive and make some growth over a much wider range of temperatures than that given for any of the groups, but the growth at temperatures outside the limits given is likely to be abnormal or retarded. In order, therefore, to insure as nearly optimum conditions for infection and decay as possible, the potatoes were incubated at some temperature within the range at which a normal growth of the species under investigation took place.

The inoculation experiments were carried out in duplicate, thirty potatoes being inoculated in each experiment. The checks (30) were treated in every way the same as the inoculated potatoes except that sterile sweet potato decoction was poured into the well.

In from 24 to 48 hours some of the potatoes were partially decayed. If the decay originated at the point of inoculation (well) an isolation was made and the organism identified.

### SOURCE OF ORGANISMS

Inoculation experiments were carried out with the following 11 species of Rhizopus: *Rhizopus nigricans* Ehrnb., *R. reflexus* Bainier, *R. chinensis* Saito, *R. tritici* Saito, *R. artocarpi* Racib., *R. delemar* (Boid.) Wehmer and Hanzawa, *R. Maydis* Bruderl., *R. nodosus* Namysl., *R. oryzae* Went and Pr. Geerlings, *R. microsporus* van Tieghem, and *R. arrhizus* Fischer.

The writers obtained all of the species except *nigricans* from Mr. E. D. Eddy, to whom they are indebted also for some preliminary work on the parasitism of some of the species. Mr. Eddy, who was formerly engaged in a monographic study of the genus, collected the various species from different sources. *Rhizopus artocarpi* was obtained from Reinking, Philippine Islands; *R. Maydis*, *R. nodosus*, and *R. delemar* from Centralstelle für Pilzkulturen, Amsterdam, Holland; *R. tritici*, *R. oryzae* and *R. chinensis* from Dr. A. F. Blakeslee. *Rhizopus reflexus* and *R. microsporus* were original isolations made by Mr. Eddy from apricots and soil respectively.

Preliminary to the inoculation experiments a pure line culture of each organism was obtained. This was done by growing the fungus on Beyerinck's agar where a comparatively few long strands of hyphae are produced. These are generally so well separated that a cutting can be made readily from a single thread.

### EXPERIMENTAL DATA

Before the different species were "pure lined" a series of inoculations were made upon sweet potatoes. It was later concluded to repeat the entire set of experiments using pure line cultures in each case. The results of the earlier experiments which were preliminary in nature are not included in the table for the reason that they would add greatly to the volume of data to be presented without in any way altering the conclusions to be drawn.

### DISCUSSION OF RESULTS

The experiments, the results of which are shown in table 1, had for their primary object to determine which of the species of Rhizopus are parasitic on sweet potatoes, and incidentally the degree of parasitism. While some conclusion might be drawn with respect to the relative degree of parasitism of the different species, a strict interpretation of the results as shown by the table would be misleading. At the outset it might be well to call attention to the fact that an attempt was made to study in a very general way the influence of temperature on infection and decay. As previously pointed out the species can be roughly grouped into high, low, and intermediate temperature forms. In some instances

TABLE 1

*Showing the number of sweet potatoes infected in each experiment by the different species of Rhizopus and the organism isolated. There were 30 checks and 30 inoculated potatoes in each experiment*

I = inoculated, C = check

| SPECIES | TEMPERATURE DEGREES C. | NUMBER OF POTATOES DECAYED | ORGANISMS ISOLATED |
|---|---|---|---|
| nigricans | 22–26 | I. 14<br>C. 1 | R. nigricans 14<br>do 1 |
| | 20 | I. 25<br>C. 1 | R. nigricans 25<br>do 1 |
| reflexus | 20 | I. 19<br>C. 1 | R. reflexus 19<br>R. nigricans 1 |
| | 20 | I. 13<br>C. 0 | R. reflexus 13 |
| chinensis | 33–35 | I. 7<br>C. 8 | R. tritici group, 7<br>R. tritici group, 8 |
| | 33–35 | I. 8<br>C. 8 | R. tritici group, 8<br>do 8 |
| tritici | 22–26 | I. 28<br>C. 0 | R. tritici 28 |
| | 22–26 | I. 30<br>C. 0 | R. tritici 30 |
| oryzae | 34 | I. 26<br>C. 0 | R. oryzae 25<br>tritici 1 |
| | 30 | I. 29<br>C. 0 | R. oryzae 29 |
| microsporus | 23 | I. 0<br>C. 0 | |
| | 14 & 18 | I. 0<br>C. 0 | |
| artocarpi | 22–26 | I. 13<br>C. 0 | R. artocarpi 13 |
| | 20 | I. 21<br>C. 0 | R. artocarpi 13 |
| delemar | 22–26 | I. 28<br>C. 0 | R. delamar 28 |
| | 22–26 | I. 20<br>C. 1 | R. delemar 20<br>R. tritici 1 |
| maydis | 22–26 | I. 14<br>C. 0 | R. maydis 14 |
| | 30 | I. 30<br>C. 0 | R. maydis 30 |
| nodosus | 34 | I. 30<br>C. 0 | R. nodosus 30 |
| | 30 | I. 30<br>C. 0 | R. nodosus 29<br>R. delemar 1 |
| arrhizus | 30 | I. 30<br>C. 0 | R. arrhizus 30 |

one of the duplicate tests was carried out at a temperature higher than the optimum for the best development of the species under investigation and as a result the percentage of infection was small. There are at least three outstanding examples as shown by the table where the percentage of infection was low because a temperature unfavorable to the growth of the fungus was employed. In the experiments with *Rhizopus nigricans* 14 out of 30 and 25 out of 30 potatoes were infected at temperatures of 22 to 26° C. respectively. Similar results were obtained with *Rhizopus artocarpi*. At a temperature of from 22 to 26° C. only 13 out of 30 potatoes were infected while at 20° C. there were 21. Both *R. nigricans* and *R. artocarpi* are low temperature forms, the percentage of infections decreasing with the increase of temperature above 20° C. It is not unlikely that even a higher percentage of infection could be obtained with both *R. nigricans* and *R. artocarpi* if the potatoes were incubated at a temperature lower than 20° C. *Rhizopus maydis*, however, is a species of quite different temperature requirements. At a temperature of from 22 to 26° C. 14 out of 30 potatoes became infected while at 30° all the potatoes decayed. *Rhizopus nigricans* and *R. artocarpi* being low temperature forms are more virulent at 20° C. or lower. *Rhizopus maydis* being one of the intermediate forms is more parasitic at 30° C. than at 22 to 26° C.

The results show that 9 of the 11 species investigated are parasitic to the sweet potato, the two exceptions being *R. chinensis* and *R. microsporus*. It is not possible to state at this time whether or not there is any variation in the degree of parasitism of the different species and if so to what extent. It might appear from the table that some species were less parasitic than others if judged by the percentage of infection alone. However, in some cases, the low percentage of infection was due to the unfavorable temperature at which the potatoes were incubated and not to any lack of parasitism on the part of the fungus.

It will be noted that the two non-parasitic species *R. chinensis* and *R. microsporus* are high and low temperature forms respectively. In the case of the former some of both the inoculated and check potatoes were decayed but none by *R. microsporus*. Potatoes inoculated with *R. microsporus* were subjected to three different temperatures viz., 14, 18 and 23° C. and in no case did infection result. Higher temperatures were not employed because preliminary work showed that the species thrived in cultures only at these or lower temperatures.

These results show that, not only *Rhizopus nigricans* but other species of the genus Rhizopus may be responsible for the losses of sweet potatoes in storage and in transit. It is not unlikely as the writers hope to show later, that other crops, both fruits and vegetables, may be decayed by other species of Rhizopus than *R. nigricans*. Although *R. nigricans* seems to be the most common species found on sweet potatoes, this ma

be due to the fact that the potatoes are for the most part held at a temperature more favorable for its growth than for the growth of the other species. When a temperature of 30° C. is reached other species of Rhizopus are found.

## SUMMARY

1. The results of the inoculation experiments show the following species of Rhizopus to be parasitic on sweet potatoes: *R. nigricans*, *R. tritici*, *R. nodosus*, *R. maydis*, *R. reflexus*, *R. artocarpi*, *R. delemar*, *R. arrhizus* and *R. oryzae*. *Rhizopus chinensis* and *R. microsporus*, the two other species tried, were not parasitic on the sweet potato.

2. The different species can be roughly grouped into high, intermediate and low temperature forms. The high temperature forms thrive best at temperatures varying from 30° to 40° C.; the intermediates, at temperatures varying from 20 to 35° C; and the low temperature forms, at temperatures ranging from 15 to 20° C. It was found that the best results from inoculations were obtained when the potatoes were incubated at the temperature best suited for the growth of the species with which the inoculations were made.

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# BRIEFER ARTICLES

## LOSS FROM RYE ERGOT[1]

EDITH K. SEYMOUR AND FRANK T. MCFARLAND

WITH TWO FIGURES IN THE TEXT

It is ordinarly assumed that the loss caused by ergot (*Claviceps purpurea* (Fr.) Tul.) in rye is directly proportional to the number of sclerotia produced. Indeed, it might be thought at first that it is represented merely by the transformation of this number of potential rye kernels into the corresponding number of worthless or poisonous sclerotia. As a matter of fact, however, field observations soon convince one that the actual damage must exceed this. The developmental processes of the parasitized inflorescences are evidently fundamentally altered. This may be attributed in part to the unusually heavy drain which the developing sclerotia may make upon the nutrition supply of the host and in part to the damage caused by the parasitic hyphae penetrating various parts of the spikes. As a result of this parasitism, there may be produced, besides the sclerotia, numerous blasted kernels and empty florets.

In order to secure evidence bearing upon these matters, observations which were initiated by Dr. L. R. Jones in the summer of 1918 have been supplemented and continued by the writers during 1919 and 1920. The results are tabulated in table 1. All observations were made on winter rye except when otherwise designated in the table. Counts in 1918 show that when there were only 3 per cent of the florets containing sclerotia there were also 35 per cent either empty or filled with blasted kernels. In 1919, three more series of observations were made. In one series in which 14 per cent of the florets contained sclerotia, 64 per cent in addition either held blasted kernels or were empty. In the second series where there were 21 per cent with sclerotia, there were 66 per cent either empty or holding blasted kernels. It should be noted here that it has been widely observed that there is a high degree of sterility in rye and so the question has arisen whether this blasting and lack of kernel development is due to the presence of the fungus or to some other factor. When the last 1919 observations on ergotized rye were made, control observations were also made on unergotized spikes, collected not only from the same field but also in close proximity to the ergotized spikes. The third

[1] Co-operative investigations between the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, and the Wisconsin Agricultural Experiment Station.

series of counts with 3 per cent of the florets containing sclerotia showed 38 per cent either empty or holding blasted kernels, whereas, in the control, the number of blasted kernels or empty florets was only 33 per cent.

In the three observations made in 1920, it was evident from the occurrence of the sphacelial exudate that the fungus may attack the spikes

TABLE 1

*Loss from rye ergot due to destruction or blasting of kernels*
(All collections were of winter rye except the last two)

| PLACE AND YEAR OF COLLECTIONS | ERGOTIZED OR UNERGOTIZED SPIKES | NUMBER OF SPIKES COUNTED | NUMBER OF NORMAL KERNELS | PER CENT. OF NORMAL KERNELS | NUMBER OF BLASTED KERNELS OR EMPTY FLORETS | PER CENT OF BLASTED KERNELS OR EMPTY FLORETS | NUMBER OF SCLEROTIA | PER CENT. OF SCLEROTIA | AVE. LENGTH (CM.) PER SPIKE | AVE. WEIGHT (CM.) PER SPIKE |
|---|---|---|---|---|---|---|---|---|---|---|
| Ellison Bay, 1918 | ergotized | 40 | 965 | 62 | 543 | 35 | 44 | 3 | | |
| Madison, 1919 | " | 52 | 531 | 22 | 1660 | 64 | 375 | 14 | | |
| Madison, 1919 | " | 21 | 175 | 13 | 902 | 66 | 282 | 21 | | |
| Edwardsville, 1919 | " | 74 | 2661 | 59 | 1709 | 38 | 154 | 3 | 10.3 | 0.9 |
| Edwardsville, 1919 | unergotized | 74 | 3291 | 67 | 1613 | 33 | 0 | 0 | 11.6 | 1.4 |
| Madison, 1920 | ergotized | 182 | 2252 | 24 | 5484 | 57 | 1797 | 19 | 10.3 | 0.9 |
| Madison, 1920 | unergotized | 239 | 10152 | 68 | 4590 | 31 | 0 | 0 | 10.8 | 1.4 |
| Burke, 1920 | ergotized | 164 | 5497 | 55 | 3744 | 38 | 661 | 7 | 10.8 | 0.8 |
| Burke, 1920 | unergotized | 139 | 5845 | 71 | 2375 | 29 | 0 | 0 | 10.7 | 0.6 |
| Madison, 1920 (spring) | ergotized | 197 | 4634 | 47 | 4580 | 47 | 575 | 6 | 8.9 | 0.8 |
| Madison, 1920 (spring) | unergotized | 199 | 7223 | 68 | 3479 | 32 | 0 | 0 | 9.7 | 1.2 |

without producing sclerotia. To obviate the danger of counting parasitized spikes as normal, 1120 spikes were tagged and numbered in the field at the time when the development of the sphacelial exudate was at its height. Of this number, 543 were ergotized, as evidenced by the presence of the exudate, and 577 were unergotized, that is, they showed no exudate. The unergotized spikes were examined about every other day to make sure that no later infection took place. When such infection did take place as evidenced by the appearance of the exudate, the newly infected spikes were included with the diseased number. The attempt was made to tag one ergotized spike and a corresponding unergotized spike in close proximity so that the two spikes might be subjected to similar environmental conditons. These spikes were found in three different localities. In the first in which 19 per cent of the florets held sclerotia, 57 per cent were empty or contained blasted kernels, whereas,

the percentage of blasted kernels or empty florets was lower in the control by 26 per cent. In the second locality where 7 per cent of the florets held sclerotia, 38 per cent were empty or held blasted kernels, with a control in which 29 per cent were similarly defective. In the third locality, sclerotia were found in 6 per cent of the florets, whereas 47 per cent of them were empty or contained blasted kerels, with a control showing 15 per cent less of similarly defective florets.

These observations of fungal destruction were further verified by examination of the florets for the presence of conidia, this being regarded as indicative of mycelial penetration. Of 24 spikes collected in Edwardsville, 30 per cent of the florets showed no conidia or sclerotia, 49 per cent

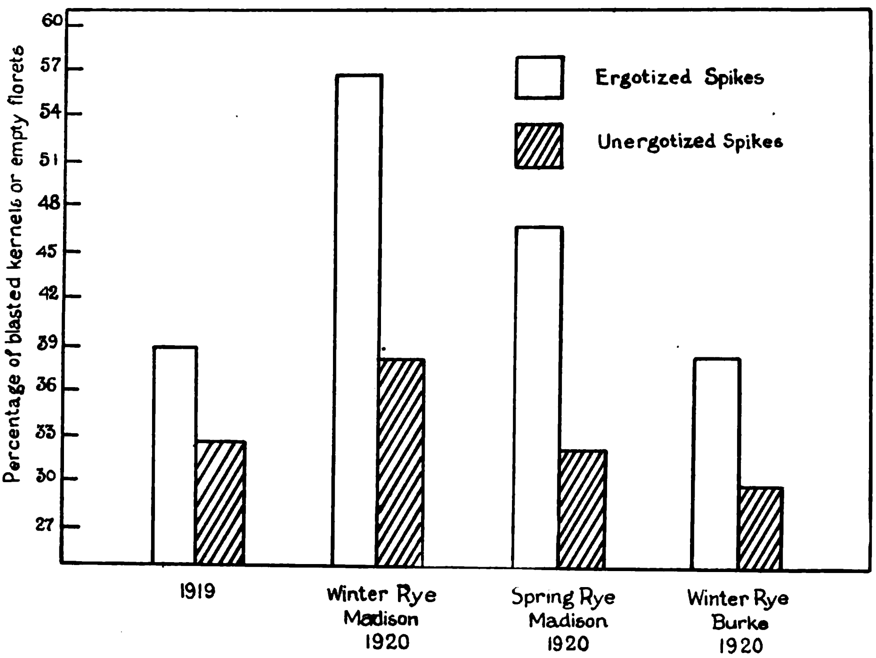


Fig. 1. Graph showing percentages of blasted kernels and empty florets, and sclerotia bearing florets in seven fields of rye.

showed abundant conidia, and 21 per cent showed sclerotia. Thus 70 per cent of the florets were infected by the fungus, although only 21 per cent contained sclerotia. Examination of 894 blasted kernels or empty florets in 20 spikes of this collection showed 64 per cent with abundant conidia, whereas only 36 per cent contained no conidia.

In order to obtain all possible data on the effect of the fungus, other observations were made. The average length and weight, sclerotia included, of the ergotized spikes was compared with that of the unergotized Of the material collected in Edwardsville, the average unergotized spike was 1.3 cm. longer and weighed 0.5 gm. more than the average ergotized spike; of the winter rye from Madison in 1920 the ergot-free spike was 0.5 cm. longer and weighed 0.5 gm. more than the infected spike; and of

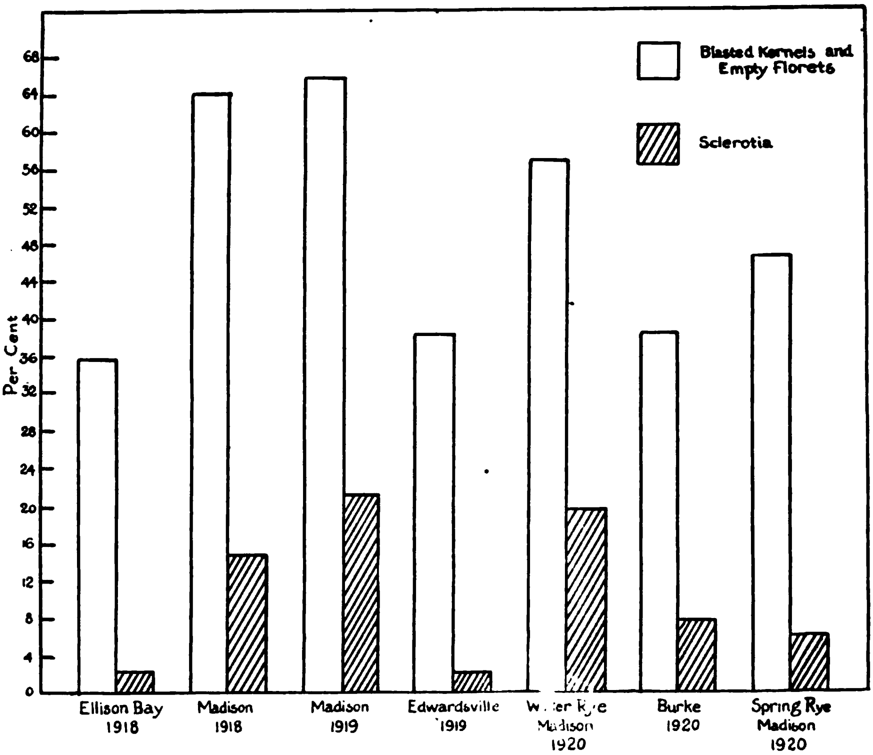


Fig. 2. Graph showing the percentages of blasted kernels and empty florets in ergotized and in unergotized heads of rye.

the spring rye collected at Madison in 1920 the unergotized spike was 0.8 cm. longer and weighed 0.4 gm. more than the ergotized spike. On the other hand, in the material from Burke, the average ergotized spike was 0.1 cm. longer and weighed 0.2 gm. more than the average unergotized spike. Our results show a shorter ergotized axis except in the case of the Burke material. If infection can take place in the oldest ovaries before the spike has attained its full growth, it is conceivable that such a retarda-

tion might be due to the fungus. In regard to the weight, even including the sclerotia, our results show a slight decrease in every case except the last.

The question of the maturity of infected and uninfected rye plants has arisen. In looking over a rye field one notices that the ergotized plants, as a rule, are later in their development than the unergotized. This effect may possibly be due to the attack of the plants normally later in maturing or to the fungus retarding the filling of the kernels. To throw some light upon whether the fungus attacks less mature spikes or retards the ripening of ergotized spikes, counts were made of the material collected at Edwardsville, which shows the following conditions:

| | | |
|---|---|---|
| Total number of ergotized spikes | 76 | 100% |
| Number of ergotized spikes immature | 53 | 69% |
| Numbes of ergotized spikes mature | 23 | 31% |
| Total number of unergotized spikes | 120 | 100% |
| Number of unergotized spikës immature | 43 | 36% |
| Number of unergotized spikes mature | 77 | 64% |

As great care was taken to collect infected plants grown under the same conditions as the unergotized plants, our counts are significant and show that the greater percentage of infected spikes are immature. This, however, does not show whether the fungus is responsible for this delay in maturity.

In summarizing, the average of the counts may be expressed as follows:

| SPIKES | PER CENT. NORMAL KERNELS | PER CENT. BLASTED KERNELS OR EMPTY FLORETS |
|---|---|---|
| Ergotized | 43 | 48 |
| Unergotized | 69 | 31 |

This tabulated average and figure 1 show clearly that in ergotized spikes there is, beside the percentage of florets containing sclerotia, a much larger percentage of florets containing neither sclerotia nor normal kernels. Further, there is always a greater percentage of these latter florets in the ergotized spikes than in the unergotized spikes (Fig. 2). Lastly, it is evident in the diseased plants that the majority of the blasted kernels or empty florets have been penetrated by the fungus. Thus it may be concluded that, due to the presence of the ergot fungus, there is a marked reduction in the yield of normal kernels beyond the simple replacement of kernels by sclerotia.

OFFICE OF CEREAL INVESTIGATIONS,
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# THE BLOSSOM BLIGHT OF THE PEACH

Mel. T. Cook[1]

With Plate XII

The *blossom blight* form of the brown rot (*Sclerotinia cinerea* (Bon.) Schröt.), has been known for a number of years but since it is not of annual occurrence in a severe form, its importance has been overshadowed by the *fruit rot* form which occurs later in the season. The *blossom blight* form of the disease is quite common in New Jersey and during the blossoming seasons of 1919 and 1920 was exceptionally severe. These two outbreaks lead the author to begin some studies which were reported at the 1920 December meeting of the American Phytopathological Society. Requests from members of the Society have induced the writer to make this preliminary report at this time.

The severity of this outbreak raised two questions: (1) The source of the infection, and (2) the most satisfactory methods of control. The life history of the organism very naturally led to the examination of the mummied fruits for Monilia and apothecia. The presence of either might be sufficient to explain the infection, but the latter is considered by many to be of major importance. The section of the state in which the disease was most severe includes a large number of orchards of various ages and sizes, and in various conditions so far as cultivation and fertilization are concerned. Therefore, the conditions for study were exceptionally favorable. A very careful study of this territory was made in both 1919 and 1920. The organism was found to be viable on many old mummies but not a single specimen of the apothecial stage could be found. However, it was impossible to correlate the disease with the presence or absence of the mummies or with the cultural conditions of the orchard. Among these orchards was one that had been planted and cared for by the Horticultural Department of the New Jersey Agricultural Experiment Station and in which it was almost impossible to find mummies of any kind. Yet a large majority of the blossoms were destroyed in 1919 and the infestation was very severe in 1920. Many other orchards in which the mummies were rare were as heavily infected as orchards in which they were abundant. In fact the studies during the past two years have indicated that the infections were due to some source other than either mummies or the apothecia.

Further studies indicated that small cankers formed at the base of the

[1] Paper No. 26 of the Journal Series. New Jersey Agricultural Experiment Stations Department of Plant Pathology.

In most cases only a few buds at the base of the shoot are infected, while in other cases as many as 75 per cent of them become infected. In some cases the base of the shoot is girdled and the entire shoot dies giving an appearance very similar to that of fire blight on the pear.

The cankers usually appear just below and at the base of the bud; they enlarge very slowly during the growing season, sometimes completely involving and killing the buds, but in most cases the buds live and produce flowers the following season. The living organism can be isolated from many of these cankers during the summer and winter. The fungus develops from these cankers during the next blooming season and if the weather is warm and moist, appears as grayish, tufted masses, bearing a great abundance of conidia. This has been the most important source of blossom infection during 1919 and 1920.

In many cases the fungus works its way outward through the pedicel and into the flowers, while in other cases the blossoms become infected from spores and the fungus works its way back into the wood and gives rise to a canker. This latter form of infection has been noted by many workers but the formation of the canker on the new growth a year in advance of blooming and thus becoming a source of infection appears to have been very generally overlooked. A brief review of the literature on this point is as follows:

In 1892 Chester (1, p. 6) wrote "This blight of the blossom had extended so far as to cause in many cases, a browning of the wood at the base of each blighted blossom."

In 1899 Cordley (2, p. 8-9) wrote "Upon the peaches and cherries the fungus usually makes its first appearance in the spring upon the flowers, about the time the petals fall." * * * * *

"In the peach, the blossoms of which have very short pedicels, the blight does not stop with the destruction of the flower, but the mycelium of the fungus may extend through the pedicel into the tissues of the twig. The portion of the twig thus attacked soon assumes the characteristic leathery brown color of brown rot. The extent of the tissue thus bud during the preceeding year were the most important factor in the the development of this stage of the disease. These cankers originate as soon as the leaf shots begin to develop, which is about the time or immediately following the opening of the flower buds. The young wood of these leafy shoots is very tender and appears to be very easily infected at this time. If the weather conditions are favorable for the development of the blossom blight, they are also favorable for the formation of new cankers. The first infections are at the bases of the shoots, other buds becoming infected in more or less regular succession throughout the season, the number depending on favorable or unfavorable conditions.

involved usually varies with the conditions of heat and moisture, but should it extend around the twig so that the latter is girdled, all of the terminal portion beyond the point of infection will blight."

Quaintance (6, p. 247, 248) in 1900 says "In the peach, particularly, the fungus does not necessarily stop its growth in the flowers, but ths mycelium may grow down through the flower stalks and attack the tissues of the twigs."

Scott & Ayres (7, p. 11) reported in 1910 that, "The fungus also attacks the blossoms and twigs, thus often destroying a portion of the fruit crop at blooming time. The diseased blossoms turn brown and become dried, adhering to the twigs for some weeks. The fungus may extend from the dead blossoms into the bark, forming a small brown canker which frequently girdles the twig. In low, damp situations, specially in a wet spring many blossoms and fruit bearing twigs may thus be destroyed."

Jehle in 1913 (4) says—"Sometimes the shuck becomes diseased and this is then shed without further injury to the pistil, but usually the entire flower becomes infected and the disease travels down the pedicel of the peach flower, finally entering the fruit spur, causing there the exudation of a large quantity of gum, which surrounds the blossom and holds it fast to the spur. Such diseased blossoms remain clinging to the fruit spurs during the entire summer, and whenever there is a sufficient moisture the typical ash grey conidia are produced in great abundance on the fruit."

In 1915 Heald (3) wrote "In case of blossom infection the fungus may advance into the fruit spurs and cause some blighting, although in the majority of flower infections the fungus does not penetrate farther than the base of the flower pedicel."

It appears that the appearance of cankers on new wood and the relation of these cankers to the infections resulting in the "blossom blight" has been very generally overlooked. It also appears that the workers have very generally attributed the formation of cankers to infected blossoms.

The flower having been killed regardless of time or source of infection the bark splits and a large gummy canker is produced which may continue active for a number of years or which may heal and form a more or less prominent scar. The writer is uncertain as to the length of time that these cankers may presist as important centers for the development of spores. When first formed they are capable of producing great numbers of spores if the weather conditions are favorable. As the season advanced they produced fewer and fewer spores, many of them ceasing to produce spores and healing completely. However, it is evident that the fungus in some of them may live for one or more years and continue to be foci or infection. These cankers have been mentioned by several workers.

BLOSSOM BLIGHT OF THE PEACH DUE TO SCLEROTINIA CINEREA. NOTE THE CANKERS AT BASES OF BUDS

Jehle (4) in 1913 and 1914 stated that "The fungus remained alive in the cankers during the winter and only needed favorable conditions to call it forth into activity." He also says "A callus is soon formed outside of the diseased area and sometimes the wound heals over, but usually this callus becomes diseased. The following year healing is again attempted and the callus usually is again invaded. This process is repeated year after year so that several such calli are formed. The writer has seen as many as five on a single canker."

Heald (3) in 1915 stated that "the fungus works down through the blossom or fruit spur into the bark and spreads to form the canker. Such cankers serve, in the same way as hold over fire-blight cankers, as centers from which new infections may originate." He also says "such cankers may continue to extend for a perod of years before the branch is girdled or the progress of the lesion checked."

In 1918 McCubbin (5) in his paper on "Peach Canker" in which he considered *Valsa leucostoma* as the factor of greatest importance says, "As far as we can see, the Brown Rot fungus acts as an initial agent only, and while it may readily bring about the first stage of cankers it is considered to play little if any part in the second stage—the succeeding yearly extension of these."

The writer is uncertain as to the length of time that the fungus will live in the cankers but it is very evident that they are of greatest importance immediately before and immediately following the blossoming and that they become of less and less importance as the season advances. The fungus undoubtedly dies in most of them during this first season. The writer is also uncertain as to the importance of *Valsa leucostoma* and other organisms in perpetuating these cankers.


## SUMMARY

1. Cankers formed on the new growth are the most important sources of infection resulting in the "blossom blight" of the peach.

2. The fungus emerging from the spores in grayish, tufted masses produces an abundance of conidia spores.

3. The blossom infection may be from these spores or by a growth of the fungus from the cankers through the pedicel and into the flower.

4. Cankers may also be produced by growth from the blossom through the pedicel and into the wood at the base.

5. Immediately following the blossoming, the cankers, split, produce an abundance of gum and if the conditions are favorable an abundance of spores. They become of less and less importance in the distribution of spores as the season advances.

6. Many of these cankers heal but some of them presist for one or more years and may continue to produce spores but are of minor importance when compared with their activity during the blossoming season.

7. The cankers are of much greater importance in New Jersey than either the Monilia as found on the mummies or the apothecia.

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## CENANGIUM PINIPHILUM N. SP., AN UNDESCRIBED CANKER-FORMING FUNGUS ON PINUS PONDEROSA AND P. CONTORTA

JAMES R. WEIR

WITH PLATE XIII AND TWO FIGURES IN THE TEXT

The species described below was first collected at Boulder, Montana, on *Pinus contorta*, on June 8, 1915. Since then it has been found abun-

FIG. 1. APOTHECIA OF CENANGIUM PINIPHILUM ON PINUS CONTORTA

dantly in the lake region of northern Idaho, where it attacks *Pinus ponderosa* and *P. contorta*. Since the fungus, in its minute and gross characters, is closer to Cenangium than any genus so far described as parasitic on conifers, it is here described as *Cenangium piniphilum* n. sp., having the following characteristics:

Apothecia appearing singly, then in groups, rupturing the epidermis, at first rounded or ellipsoidal, closed, then cone-shaped, tapering to a stem-like base, expanding and becoming almost plane with the margin, irregularly incurved, but not wholly closed when dry, coriaceous, membranaceous, 2–5 mm. across, carbonous; disc brownish to black, surface velvety or wrinkled; asci clavate, rounded above, long stipitate, averaging 135.8 x 14.1μ, 8-spored; spores irregularly 2-seriate, sometimes 1-seriate, oblong to ellipsoid or fusiform, extremities acute, usually with a single central oil drop, occasionally with two, hyaline, continuous, averaging 18.9 x 6.4 μ; paraphyses filamentous, branched, longer than the asci, hyaline.

Type collected on a 15-year tree of *Pinus contorta* at Priest River, Idaho, in the Kaniksu National Forest, May 12, 1920, common throughout northern Idaho, eastern Washington and western Montana. Type material deposited in the Office of Pathological Collections, and Office of Investigations in Forest Pathology, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. (Weir Herb. 14973).

This fungus, which is of considerable silvicultural significance, attacks *Pinus ponderosa* and *P. contorta* between the ages of 5 to 25 years, or older. Infection usually occurs at the nodes, less frequently on the internodes, but may eventually spread throughout the entire length of the stem. The mycelium penetrates the cortex, phloem, and wood, and causes a canker (Plate XIII, fig. A). The cambium is killed, preventing any further growth in thickness at the point of infection, and with each year's increment the outline of the tree in cross section becomes more irregular (Pl. XIII, fig. B). The penetration of the mycelium into the cortex, phloem, and wood causes the exudation of large quantities of resin on the surface of the canker, which runs down the bark very conspicuously (Pl. XIII, fig. A). The dark brown, extensively branched mycelium following chiefly the medullary rays in the wood (Pl. XIII, fig. C) imparts to it a grayish or bluish-black color (Pl. XIII, fig. B) resembling that caused by *Ceratostomella pilifera* (Fr.) Wint. This color may extend to varying depths or entirely through the tree in the case of two oppositely arranged cankers (Pl. XIII, fig. B). The color, which is always indicative of the presence of mycelium, may

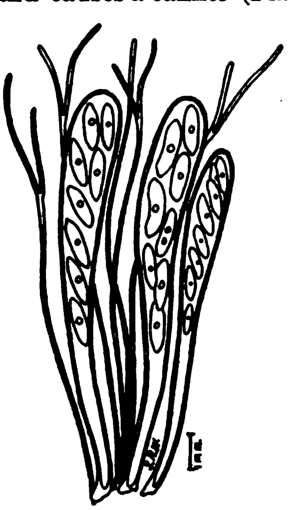

FIG. 2. MATURE ASCI ASCOSPORES, AND PARAPHYSES OF CENANGIUM PINIPHILUM.

extend from one canker to another up and down the tree and is very conspicuous in longitudinal section. Brownish-black deposits in the various cells, especially in the resin passages and medullary rays, intensify the color (Pl.XIII, figs. C, D). The mycelium grows both in the cells and in the intercellular spaces. The stalked apothecia (Fig. 1), containing long stipitate asci with 8 oblong spores (Fig. 2), are borne on the dead bark of the canker and vary in size according to the age of infection. Thefact that infection usually occurs at the branch whorls indicates a natural weakness at this point and may not be due to wounds. Wounds caused by various agents are, however, a source of infection, as has been demonstrated by experiments. The transfer of spores to incisions in the bark of young trees always result in infections. Such infections as occur at the base of branches spread to the main trunk, frequently involving the entire circumference at this point. The number of cankers on a single tree is in some cases limited only by the number of whorls. A 15-year-old tree may have as high as 10, or more, separate and distinct cankers. All of these cankers may be united internally by discolored wood. A thin ridge of tissue winding from one canker to another may be all that remains uninfected.

Although the fungus grows readily on artificial media, it has not yet been induced to form apothecia. The mycelium on artificial media breaks up into conidia, a condition not observed in nature.

The fungus thrives best in dense, moist stands, where the reproduction is over crowded.

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CENANGIUM PINIPHILUM N. SP.

Fig. A Canker on *Pinus contorta* caused by *Cenangium piniphilum*, showing apothecia and exudation of resin; Fig. B. Cross section of canker on *Pinus contorta* showing irregularity and discoloration of infected wood. × 1⅓; Fig. C. Tangential section of wood of *Pinus contorta* attacked by *C. piniphilum*. Note dark contents of the tracheids and medullary rays. × 110; Fig. D. Cross section of infected wood showing dark contents of the resin canals, medullary rays and tracheids. × 110.

## PHYTOPATHOLOGICAL NOTES

*Angular leaf-spot of cucumber*.—During the summer of 1919, an experimental planting of a strain of pickling cucumber was made at Ellison Bay, Wis., in a soil which, so far as known, had never before grown cucumbers. The primary purpose of this was to determine whether or not the mosaic disease might overwinter with the seed. To this end, the seed had been collected the year before, largely with the assistance of Dr. M. W. Gardner, at Grass Lake, Mich. In each collection the fruits were taken from mosaic plants. No record was made of the occurrence of other diseases on these mother plants but angular leaf spot is known to have been severe in the fields where seed was collected.

Although the results were purely negative as regards mosaic, there was a very interesting development as regards the angular leaf spot. These plants were watched critically, the field being gone over plant by plant at frequent intervals during the season. On July 24, following a few days of warm, misty weather, including one or two gentle showers, there appeared a considerable development of angular leaf spot upon a single hill in the interior of the field. There were two plants in the hill, the disease at this stage appearing simultaneously upon leaves of both. From this as a center, the disease spread rapidly during the next fortnight, the dissemination being essentially radial, probably as a result of the spattering of rainwater, since no insects were in evidence and there was no promiscuous picking or other passing through the field.

Before the end of August, the disease was in evidence over much of this field, comprising nearly one-half acre. One of the most striking things was that although the damage from foliage destruction threatened to be quite serious under the favorable moist weather conditions of the first two weeks, with the subsequent advent of a fortnight or more of dry weather, this type of development was so much inhibited as to become of relatively minor practical importance. On the other hand, before the end of August the development of fruit infection proved very serious indeed. This fruit infection ultimately became so prevalent as to include the appearance of watersoaked spots upon the fruits before they were a quarter grown, and by the time they reached the larger pickling sizes they were often ruined. The two things, then, of special significance from these observations, as supplementing those recorded in the publications of Carsner (Jour. Agric. Res. **15**: 201–220, 1918) and Gilbert and Gardner (Phytopath. **8**: 29–33, 1908), are the fact of its overwintering

on the seed and its serious destructiveness on the young fruit in the field. —L. R. JONES AND S. P. DOOLITTLE.

*Field tests with cucumber angular leaf-spot and anthracnose.*—During 1918, 1919 and 1920, field tests bearing upon the overwintering of the organisms causing angular leaf-spot and anthracnose of cucumber were conducted on a seed farm at Grass Lake, Michigan, and in 1918 at Plymouth, Indiana.

The effectiveness of seed disinfection in mercury bichloride, 1-1000, for five minutes as a control for the angular leaf-spot[1] was further demonstrated. This treatment does not eliminate absolutely all of the infection, but for practical purposes is very effective since it materially reduces the number of original centers of infection, delays the appearance of the disease and prevents its occurrence in epiphytotic form. At Plymouth, Indiana, anthracnose was rather abundant in a plot planted with untreated seed, while only a trace appeared in a similar plot planted with treated seed. Large scale seed disinfection has been practiced by the H. J. Heinz Company for the last three years with very satisfactory results. The cucumber seed is assembled at a branch factory in quantities up to several tons where it is treated in barrels in fifty-pound lots and spread out over a large floor space to dry.

The Grass Lake field tests indicate that the angular leaf-spot organism (*Bacterium lachrymans* E. F. S. and Bryan) survived twenty months but not thirty-two months on the seed. Thus two-year-old seed cannot be considered free from this organism and should be treated, while three-year-old seed apparently does not carry infection.

Evidence that this organism did not persist in the soil over the winter of 1918-19 was also obtained. Part of a field in which angular leaf-spot was severe in 1918 was planted with disease-free seed in 1919 and none of the disease appeared. Another portion of this field was planted with beans in 1919 and cucumbers again in 1920 and no angular leaf-spot appeared in this crop. Apparently soil infestation is not a great danger in the case of this disease.

As previously reported, the anthracnose fungus (*Colletotrichum lagenarium* (Pass.) Ell. and Hals.) was found to persist one winter in the field.[2] This field in which anthracnose was present in 1917 and 1918 was planted with a non-cucurbitaceous crop in 1919 and then with cucumbers again in 1920. No anthracnose appeared in 1920 which indicates that the

[1] Gilbert, W. W., and Gardner, M. W. Seed treatment control and overwintering of cucumber angular leaf-spot. Phytopathology **8**: 229–233. 1918

[2] Gardner, M. W. Anthracnose of cucurbits. U. S. Dept. Agric. Bull. **727**: 58. 1918.

fungus did not persist twenty months in the soil. Thus a two-year rotation should eliminate anthracnose soil infestation.—MAX W. GARDNER AND W. W. GILBERT.

*Overwintering of the bacterial wilt of cucurbits.*—During the course of studies of cucurbit mosaic conducted at Madison, Wisconsin, by the U. S. Department of Agriculture in cooperation with the Department of Plant Pathology of the University of Wisconsin, trials were made each year from 1917 to 1920 to determine whether the striped beetle, *Diabrotica vittata*, might be an agency in the overwintering of the mosaic disease. While no evidence has been secured which indicates that the insect is concerned in mosaic overwintering, there have been interesting results in regard to its relation to the overwintering of the bacterial wilt, caused by *Bacillus tracheiphilus* Erw. Sm.

In the spring of 1917, approximately 300 beetles were collected in the open field between May 25 and June 6, at the time they first appeared and before any cultivated cucurbits had been planted in the vicinity. One lot of 50 of these beetles was placed in a cage in the greenhouse together with  0 healthy young cucumber plants of small size. Between June 03 and 05 four of the plants showed definite symptoms of bacterial wilt, the cut stems in all cases having the stringy ooze characteristic of the disease.

During the spring of 1919, similar results were again obtained in the course of the trials, about 1000 beetles being tested between April 29 and May 29. On May 25, 50 beetles were collected in the field and placed in the greenhouse in a cage containing 22 healthy cucumber plants each having from four to six leaves. On June 7 three of these plants developed the symptoms of bacterial wilt and were at once removed, but no further wilt infection occurred. No wilt developed during any other of the trials made with the striped beetle during 1919.

No other cases of bacterial wilt have been noted in the greenhouse at Madison during the past four years, and at the time the beetles were collected, both in 1917 and 1919, no cultivated cucurbits had appeared in the neighborhood. Although the striped beetle feeds on the wild cucumber, *Micrampelis lobata*, prior to the appearance of other cucurbits, no signs of wilt have ever been observed either on this host or on *Sicyos angulatus*, which also occurs in the vicinity, and, while the Micrampelis is known to be an agency in overwintering cucurbit mosaic, there has been no evidence to indicate that it is concerned in the case of bacterial wilt.

It has already been shown by Rand and Enlows (U. S. Dept. Agric. Bull. 828, 43 p. 1920) and Rand and Cash (Phytopathology **10**: 132, 1920) that the striped beetle probably carried the wilt organism through the winter, and the above observations seem to support their findings in this regard.—S. P. DOOLITTLE.

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# PHYTOPATHOLOGY

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AUGUST, 1921


## A CONTRIBUTION TO OUR KNOWLEDGE OF SOIL RELATIONSHIPS WITH CITRUS CHLOROSIS


C. B. Lipman


In recent years the subject of chlorosis of plants has received much attention at the hands of investigators. Moreover, such recent investigations have resulted in the discovery of more definite "leads" toward a solution of the problem than any of those carried out prior to eight or ten years ago. We are indebted to Mazé for a clear definition and description of the conditions of chlorosis, to Gile and his associates for some fundamentally important data relative to the possible causes of the disease, and their removal, and to M. O. Johnson for a strikingly successful application of the principles set forth by the other investigators to the problem of pineapple chlorosis in the Hawaiian Islands. All of these are too well known to my readers to necessitate detailed discussion here. Despite all this, however, the problem of citrus chlorosis has seemed to remain proof against all attempts to discover an unequivocal answer for a cause and a cure therefor. While a lack of usable iron for the normal functioning of the chlorophyll in citrus leaves has seemed and still seems the best explanation for the cause of citrus chlorosis, many puzzling features surround the disease which inhibit our taking a definite stand with respect to the matter. It will be profitable for us, therefore, to advert to the conditions which the writer in common with W. P. Kelley and perhaps others, has found to obtain in chlorotic citrus orchards of California.

In my experience, the marked yellowing or even blanching of the entire leaf of the citrus tree always occurs on soils which have either a large excess of calcium and magnesium carbonates (calcareous subsoils) or a large excess of sodium and potassium carbonates. In both cases, the reaction of soil and soil solution is markedly alkaline. Usually the corral soils give marked effervescence when treated with acid. The soil of the corral is very soft and ashy in consistency. It is so markedly different in this respect from the normal soil which surrounds it that the

difference in resistance to the pressure of the feet when one steps from the corral to the normal soil is at once noticed. As would be expected from the foregoing, the corral area is very sharply delimited from the normal soil around it. This delimitation is just as marked in the appearances of citrus trees in an orchard which includes both corral and normal soils.

Whether or not the chlorosis on the two types of abnormal soils mentioned above is identical in nature, it is difficult to say with finality. There are certain differences in the appearance of trees and foliage between the two cases which counsel caution in rendering a decision on the point in question, and yet, in general, the disease seems to be the same. The two abnormal soil conditions are, however, quite distinct from each other. The highly calcareous subsoils are most frequently found underlying heavy, black adobe or "dry bog" soils at a depth of from 12 to 24 inches. The highly basic soils, rich in alkali carbonates, of the second type of chlorotic citrus trees usually occur in narrowly delimited areas known to farmers as old sheep corrals or old campfire circles, usually the former. The burden of this paper concerns itself with a comparative study of the water soluble matter in the soil of an old corral and that adjacent to it just outside the limits of the corral. The trees on the corral soil were found to be badly chlorotic. Those on the adjacent soil were in practically all respects normal or, at any rate, free from chlorosis.

Samples of soil were taken from the affected and the normal areas in such a manner that successive, eight-inch depths down to a total of twenty-four inches were represented. In other words, three layers of the soil were each represented by a composite sample from each area. These soil samples were sent to the laboratory and were extracted with water, one part of soil and two parts of distilled water being used for preparing the extracts. The latter were filtered after several hours of contact between soil and water had been allowed. In addition to this procedure, another was followed, namely the mixing of the samples from the three different depths, thus giving one composite sample for the twenty-four inch column. The composite sample of the whole column was extracted similarly to the others. This experiment was carried out prior to our investigations on soil variability and was, therefore, not as well controlled in that respect as it should have been. The difference between the normal and abnormal soils are so great, however, and especially as regards certain important constituents, as to preclude the factor of variability from affecting the results and conclusions in any significant way.

The soil extracts described were analyzed by the carefully devised methods for the analysis of water extracts in vogue in this laboratory, and largely perfected in the laboratory of Agricultural Chemistry at this university. The results of the analyses are given in table 1. The soil from the corral is designated "corral" in the table. The soil from among the unaffected trees is marked "normal."

TABLE 1

*Analyses of soil extracts of corral and normal soils*

| | 8 IN. DEPTH | | 16 IN. DEPTH | | 24 IN. DEPTH | | COMPOSITE OF 24 IN. COLUMN | |
|---|---|---|---|---|---|---|---|---|
| | CORRAL P. P.M. | NORMAL P. P.M. | CORRAL P. P.M. | NORMAL P. P.M. | CORRAL P. P.M. | NORMAL P. P.M. | CORRAL P. P.M. | NORMAL P. P.M. |
| Total solids.... | 576 | 728 | 336 | 412 | 432 | 468 | 1344 | 1608 |
| Non-volatile solids....... | 404 | 452 | 104 | 224 | 280 | 208 | 788 | 884 |
| Volatile solids.. | 172 | 276 | 152 | 188 | 152 | 260 | 476 | 724 |
| $NO_3$........ | 96 | 376 | 56 | 128 | 48 | 320 | 200 | 824 |
| Fe......... | 9 | 8 | .. | .. | .. | .. | 9 | 8 |
| Ca......... | 16.0 | 67.8 | 14.2 | 48.8 | 11.8 | 63.8 | 42 | 180.4 |
| Mg......... | 9.3 | 15.4 | 6.3 | 11.7 | 5.6 | 18.9 | 21.2 | 46.0 |
| P.......... | 16.0 | 7.2 | 12.7 | 1.6 | 18.6 | 3.6 | 47.3 | 13.4 |
| K.......... | 28.6 | 26.8 | 37.8 | 16.3 | 28.6 | 10.8 | 95.0 | 53.9 |
| Na......... | 81.0 | 45.6 | 21.8 | 27.6 | 48.7 | 19.1 | 151.5 | 92.3 |

It can be seen even from a cursory examination of the data that the comparison of the extracts from the corral and the normal soils is very striking. To do proper justice to the evidence, it is, perhaps, best to consider briefly the comparison of each of the constituents determined as between the two extracts. The total, volatile, and non-volatile solids may perhaps be considered together. In all cases, but one, the normal soil contains more of each of these constituents than the corral soil, and this is particularly marked in the composite sample for the twenty-four inch column of soil. On á priori grounds, one would expect the volatile solids to be higher in the sheep corral soil than in the normal soil, but that is evidently not the case. Whether the difference is due entirely to the difference in nitrate content between the two soils, is not clear from the data, though it is probable that that is not so.

The nitrate content of the normal soil is enormously greater than that of the corral soil. This, again, is a condition which one would not expect both from a consideration of the corral soil and from that of the greater assimilation of nitrates by the trees on the normal soil.

The situation with regard to the iron content of the two soil extracts is one which has contributed to the statement made above relative to the

need for caution in arriving at conclusions relative to the cause of citrus chlorosis. While there is much indirect and perhaps some direct evidence that a deficiency of iron exists in the chlorotic trees or soils on which they are grown, the data in table 1 give no support for such a conclusion. While there seems to be practically no iron in solution in the subsoils of both corral and normal soils, the surface layers of the two soils seem to contain approximately the same amounts of that constituent. It appears clear that a lack of soluble iron per se in the soil cannot be accountable for the chlorotic condition of the trees in question, otherwise the trees on the normal soil also should be chlorotic.

The calcium and magnesium contents are throughout markedly higher in extracts of the normal than in those of the corral soils. This is particularly true of the calcium content which is from over three to over five times as high in the normal soil extract as in that of the corral soil. This is consonant with the general idea expressed by Kelley and Cummins[1] relative to the calcium contents and perhaps calcium needs of citrus trees with particular reference to its bearing on that other still mysterious citrus disease "mottle-leaf." In general, it would seem that the water soluble supply of calcium and magnesium is insufficient in the corral soil, particularly when the important concept is appreciated that solubility does not necessarily connote or imply availability.

When we come to a consideration of the phosphorous content of the two soil extracts, we find for the first time in our study, that the corral soil is richer than the normal soil. It is not only richer but is markedly so. Indeed, the figures for the phosphorous content of the corral soil extract are decidedly abnormally high, even if both extracts show a high phosphorous content. This is particularly apparent in the extract from the composite twenty-four inch columns. This reversal in characteristic between the two soil extracts as between the constituents above discussed and phosphorous, can hardly be without significance. Without further data and further study, however, I am not prepared to hazard a hypothesis on the nature of its significance.

The strikingly unusual situation just mentioned with regard to phosphorous is further emphasized in regard to the potassium and sodium contents of the two soil extracts. Both in the different eight-inch soil extracts and in the composite samples for the twenty-four inch column the potassium and sodium are markedly higher in the corral than in the normal soil extract. Indeed they are plentiful enough in the corral soil extract as shown by the analyses for the composite sample to indicate possible direct injury to the trees from excess of those bases alone.

[1] Kelley, W. P. and A. B. Cummins, Composition of normal and mottled citrus leaves. Jour. Agric. Res., **20**: 161–191. Nov. 1920.

When the high hydroxyl-ion concentration, and the relatively high content of other anions in the corral are taken into consideration, the case looks even stronger.

That in these two markedly different soils the grouping of the $NO_3$, Ca and Mg on the one hand and the P, Na and K on the other, should be diametrically opposite, appears to me to be of very profound significance, especially when taken in conjunction with the important findings of Kelley and Cummins regarding the composition of normal and "mottle-leaf" citrus tissue. We may find in these circumstances the key to the solution of one of our most important problems in physiological balances as related to plant growth in a medium like the soil solution. The abnormalities, whatever they may be found later to signify, are apparent at once in the case of the corral soil. It is not often that one encounters such satisfying and striking divergences in comparative studies of soil extracts or soil solutions from soils situated so close to each other. The data are particularly astounding and, to me, very significant as regards the relationships of the Mg and P in the corral and the normal soils.

## SUMMARY

In a comparative study of soil extracts from soils which bear respectively normal and chlorotic citrus trees, the following interesting facts were adduced. The chlorotic trees grow in a sharply delimited area in the orchard studied and seem to be confined to areas known as sheep corrals. The latter may represent soil modified by much organic excreta but may also contain wood ash from camp fires, and ash from burnt brush or prunings.

1. In the soil extracts, the total solids, nonvolatile solids, volatile solids, nitrates, calcium, and magnesium are very much greater in extent in the normal than in the corral soil. Not only are the relative values markedly different in the two cases, but the absolute figures are very high for the constituents named in the normal soil and not so for the corral soil.

2. Just the reverse is true as between the two soil extracts for the following constituents: phosphorous, potassium, sodium.

3. There is no clue to an explanation of the chlorosis in the data for the iron content of the two soil extracts.

4. A hint of the possible correlation between the composition of the soil extracts and the discovery of the cause of the disease in this case is given.

# THE REACTION OF FIRST GENERATION HYBRID POTATOES TO THE WART DISEASE

C. R. ORTON AND FREEMAN WEISS[1]

The striking differences in the reaction of different potato varieties to the presence of the potato wart organism, exhibited in a range comprising all degrees of susceptibility up to complete and apparently permanent immunity is the most noteworthy feature of this disease from both the scientific and practical standpoints. Varietal tests have been carried on in England and in Germany which have set at rest all doubt that immunity to the wart disease is an inherent varietal character quite as specific and consistent as those upon which horticultural classification is based. Similar tests conducted in America, while less extensive as regards number and duration, point no less certainly to this same conclusion. The genetic behavior of this character has therefore been the subject of much interest since the discovery of immune varieties. Appel[2] has discussed the heritability of the immune character as brought out by results obtained in Germany from tests which included both the parents and the progeny of a number of standard varieties. At that time, the information available as to the parentage of many varieties, and the reaction of the parents to the wart disease was too meager to indicate more than that a variety might transmit its immunity or susceptibility to its progeny. In England the varietal tests have included both a large number of named varieties and also a very large number of seedlings (839 in 1919) which had been sent in for trial by seedsmen and gardeners.[3] Seedlings received in this way are not likely to be accompanied by authentic records of the parentage, and the present writers are not aware of any report in which the behavior of these seedlings with respect to the wart disease has been discussed in relation to that shown by the parents.

[1] Joint contribution from the Federal Horticultural Board, and from the Department of Botany of the Pennsylvania State College, No. 34.

[2] Appel, Otto. Über die Anfälligkeit und Widerstandsfähigkeit verschiedener Kartoffelsorten gegen Krebs. Arb. Ges. Förderung Bau. Wirtsch. Zweckm. Verwendung Kartoffeln. Heft **15**. *19 p., fold. tab.* 1918.

[3] Taylor, H. V. The distribution of wart disease. Jour. Min. Agric. London **27**: 733–738, 1920; 946–953, 1921.

In the varietal tests conducted at Freeland, Pennsylvania, and at Thomas, West Virginia, by the United States Department of Agriculture in cooperation with the agricultural experiment stations of these states, exceptionally favorable material for a study of the genetics of immunity to the wart disease has been available in a large collection of seedlings furnished by the Office of Horticultural and Pomological Investigations of the Federal Department of Agriculture. It has not yet been possible to test the parents of all these varieties, yet the reaction of a sufficient number of them has been determined to indicate clearly the heritability of the immune character and its behavior in the first hybrid generation. An extensive $F_2$ generation of a number of these hybrids, derived, however, from seed balls formed from open pollination, is now being grown and will be tested in 1921. Further crosses will be made and an $F_2$ generation from controlled pollination will be grown this year also.

The subjoined tables show the numbers and the reaction of all seedlings which have been tested, together with their parentage and the reaction of the parents, in most cases as determined by our own tests, but in a few instances as taken from published reports of European trials.

It is obvious that these data are inadequate for a clear definition of the genetic character of immunity, yet it may not be unprofitable to discuss them with regard to certain probabilities which maybe inferred. Ten hybrids have been tested which have resulted from the cross, immune $\times$ susceptible, or its reciprocal; of these, six are classed as immune and four as susceptible. This approximation to a 1:1 ration is in accordance with expectations if one of the parents, heterozygous for the dominant character, were back-crossed with a pure recessive. No clue is here given as to which character is dominant. Twelve hybrids have been derived from crosses between two susceptible parents and all are themselves susceptible. In connection with the hypothesis advanced above this would indicate that susceptibility is recessive. By this same hypothesis one would expect families derived from immune parents in general to include twenty-five per cent of susceptible forms. Some families should, however, be composed of all immunes. Unfortunately no data are as yet available regarding the behavior of hybrids derived from the cross immune $\times$ immune.

On the other hand, field observations show that some of the hybrids, as is also the case with some named varieties, exhibit various degrees of resistance, falling short, however, of immunity. The tendency toward resistance is shown both in the relatively low number of infected tubers (in some cases not more than one per cent), and in the slight

TABLE 1

*Reaction to wart disease of the parental and $F_1$ generation of potato seedlings bred by the U. S. Department of Agriculture**

| SEEDLING NO. | PARENTAGE PISTILLATE PARENT GIVEN FIRST | PISTILLATE PARENT REACTION | STAMINATE PARENT REACTION | HYBRID |
|---|---|---|---|---|
| 37662 | Early Vicktor × Projata | — | ±[4] | 0 |
| 3165 | Sophie × Irish Seedling | ++[5] | — | 0 |
| 38899 | Prosperity × Farys | — | — | 0 |
| 39304 | Dibble's Russet × McCormick | ++ | 0 | 0 |
| 39168 | Green Mountain × Busola | 0 | ++ | 0 |
| 38742 | Late Blightless × Busola | — | ++ | 0 |
| 1638 | Sophie × Keeper | ++ | 0 | 0 |
| 39305 | Dibble's Russet × McCormick | ++ | 0 | 0 |
| 39536 | Irish Cobbler × Busola | 0 | ++ | 0 |
| 39156 | Green Mountain × Petronius | 0 | + | 0 |
| 39419 | Green Mountain × S. 2321 | 0 | — | 0 |
| 20026 (No. 19) | ? ? | — | — | 0 |
| 38814 | Non-Blight × Busola | ++ | ++ | + |
| 38678 | Non-Blight × Zbyszek | ++ | ++ | ++ |
| 39215 | President Roosevelt × Busola | — | ++ | ++ |
| 39366 | Manila × Petronius | — | + | ++ |
| 38859 | Non-Blight × Petronius | ++ | + | + |
| 39324 | Manila × Busola | — | ++ | ± |
| 4240 | Professor Maercker × Silver Skin | ±[4] | — | ++ |
| 17042 | Early Excelsior × Apollo | — | — | ++ |
| 38748 | Rust Proof × Busola | — | ++ | ++ |
| 38967 | Rural New Yorker × Busola | ++ | ++ | ± |
| 39500 | Irish Cobbler × Busola | 0 | ++ | + |
| 39340 | Manila × Busola | — | ++ | + |
| 38759 | Carman No. 3 × Busola | ++ | ++ | ± |
| 39379 | Manila × Petronius | — | + | ± |
| 39247 | Early Rockford × Petronius | — | + | ++ |
| 38461 | Vigorosa × Busola | — | ++ | + |
| 39622 | Irish Cobbler × Petronius | 0 | + | ++ |
| 39266 | Non-Blight × Busola | ++ | ++ | ++ |
| 39315 | Dibble's Russet × Cacha Negra | ++ | — | ++ |
| 24642 | Aroostook Wonder × Sutton's Flourball | — | 0 | ++ |
| 17365 | Empire State × Keeper | — | 0 | + |
| 37803 | Irish Cobbler × Busola | 0 | ++ | ++ |
| 38769 | Carman No. 3 × Busola | ++ | ++ | ++ |
| 38774 | Carman No. 3 × Busola | ++ | ++ | + |
| 38816 | Non-Blight × Busola | ++ | ++ | ++ |

TABLE 1 (Continued)

| SEEDLING NO. | PARENTAGE PISTILLATE PARENT GIVEN FIRST | PISTILLATE PARENT REACTION | STAMINATE PARENT REACTION | HYBRID |
|---|---|---|---|---|
| 38880 | Non-Blight × Petronius | ++ | + | ± |
| 38946 | Prosperity × Busola | —— | ++ | ± |
| 38988 | Sir Walter Raleigh × Busola | ++ | ++ | ++ |
| 39118 | Rural New Yorker × Petronius | ++ | + | ++ |
| 39206 | Green Mountain × Busola | 0 | ++ | ± |
| 39256 | Early Rockford × Petronius | —— | + | + |
| 39285 | Non-Blight × Busola | ++ | ++ | ++ |
| 39327 | Manila × Busola | —— | ++ | + |
| 39336 | Manila × Busola | —— | ++ | + |
| 39374 | Manila × Petronius | —— | + | ++ |
| 20050 (No. 6) | ? ? | —— | —— | + |

* ++ indicates very susceptible or over 50 per cent of tuber infection.
+ indicates susceptible, or from 10 to 50 per cent of tuber infection.
± indicates slight susceptibility, or less than 10 per cent of tuber.
0 indicates complete freedom from infection.
A long dash indicates that the reaction of the variety is not known.

development of warty outgrowths from such infections as occur. Repeated tests have yielded concordant results for a given variety both in Europe and in our own work and the possible existence of different strains of the pathogene exhibiting variable virulence is therefore not credited. Instead such differences in the degree of resistance or susceptibility shown are believed to be inherent in the variety itself and this would indicate that the extremes of resistance and susceptibility are dependent for their expression upon more than a single factor difference.

In this connection it is worthy of note that the cross Irish Cobbler × Busola, repeated three times, has yielded one hybrid classed as immune, one as moderately resistant and one as very susceptible. Green Mountain × Busola has given in one instance an immune, and in another a slightly susceptible, progeny. Prosperity × Farys has given similar results. In two instances, one the cross Rural New Yorker × Busola and the other Carman No. 3 × Busola, the combination of two susceptible parents has yielded a hybrid which appears to be highly

[4] Schaffnit, Ernst and G. Voss. Versuche zur Bekämpfung des Kartoffelkrebses im Jahre 1915–1917. Zeitschr. Pflanzenkrankh. **26**: 183–192, 1916; **27**: 339–346, 1917; **28**: 111–114, 1918.

Schaffnit, Ernst. Versuche zur Bekämpfung des Kartoffelkrebses im Jahr. 1918–19. Zeitschr. Pflanzenkrankh. **30**: 59–67, 1920.

[5] Appel, O. Op. cit.

TABLE 2

*Summary of reaction of $F_1$ generation in relation to that of parent generation*

| PATERNAL GENERATION | | NO. OF CROSSES | $F_1$ GENERATION | |
|---|---|---|---|---|
| PISTILLATE PARENT | STAMINATE PARENT | | SUSCEPTIBLE | IMMUNE |
| Immune | Immune | 0 | — | — |
| Immune | Susceptible | 7 | 4 | 3 |
| Immune | Unknown | 1 | .. | 1 |
| Susceptible | Immune | 3 | .. | 3 |
| Unknown | Immune | 2 | 2 | .. |
| Susceptible | Susceptible | 13 | 13 | .. |
| Susceptible | Unknown | 3 | 2 | 1 |
| Unknown | Susceptible | 15 | 13 | 2 |
| Unknown | Unknown | 4 | 2 | 2 |

resistant. Such apparent discrepancies are not unexpected when so small a number of plants and so few tests are considered. The effect of ecologic factors upon the development of the disease is also of great importance. Only much more extensive data will make a complete analysis possible.

The prediction seems warranted, however, that the aim of obtaining by hybridization an immune potato conforming otherwise to the type of the Rural New Yorker will be attained only by resorting to pollen parents from a different group as all the varieties of the Rural group seem to be highly susceptible.

DEPARTMENT OF BOTANY
THE PENNSYLVANIA STATE COLLEGE,
AND
FEDERAL HORTICULTURAL BOARD
U. S. DEPT. OF AGRICULTURE

# STUDIES ON THE CERCOSPORA LEAF SPOT OF BUR CLOVER

E. F. HOPKINS[1]

WITH PLATE XIII AND XIV AND THREE FIGURES IN THE TEXT

The Southern bur clover *Medicago maculata* Willd. one of the most promising leguminous forage crops in the South[2] is severely attacked by *Cercospora medicaginis* E. & E. which causes a characteristic spotting of the leaves. The disease is of wide occurrence and because of its severity is one of the limiting factors in the successful production of this important crop.

## SYMPTOMS

Characteristic symptoms of this disease on the leaves are shown in figures 1, 2, and 3. The spots begin as small circular, olivaceous or brown patches dull in lustre with a slightly irregular margin. The color of the spots is apparently due to a superficial growth of mycelium. They may originate either at the margin or towards the center of the leaflet and later enlarge until the whole leaflet or whole leaf is involved. A lesion developing towards the center of a leaflet causes a bleaching of the reddish brown leaf marking of the host. Frequently lesions occur on the leaf petiole in such a manner as to cause the death of the entire leaf.

On the seeds which have been separated from the burs the disease is exhibited by the dark appearance of the seed coats which on closer inspection will be seen to be covered partly or entirely by a network of dark strands. In figures 4, 5, and 6 the contrast between diseased and healthy seeds is brought out.

## OVERWINTERING

The symptoms on the seeds have been briefly described by the writer.[3] The dark strands are made up of hyphae of Cercospora (Fig. 7) and constitute apparently the chief method of overwintering rather than by means of viable conidia in the burs as Wolf has suggested.[4] The fact

[1] The following studies were made by the writer while at the Alabama Agricultural Experiment Station, Auburn, Ala.

[2] Cauthen, E. F. Southern bur-clover. Alabama Agric. Exp. Sta. Bull. 165: 165–176. 1912.

[3] Hopkins, E. F. Overwintering and control of bur-clover leaf-spot. Phytopathology 10: 66. 1920.

[4] Wolf, Frederick A. Dissemination of bur-clover leaf-spot. Phytopathology 6: 301. 1916.

that the mycelium is on the seeds easily accounts for the observation of Wolf[4] that in the field cotyledons are frequently found to be infected by Cercospora.

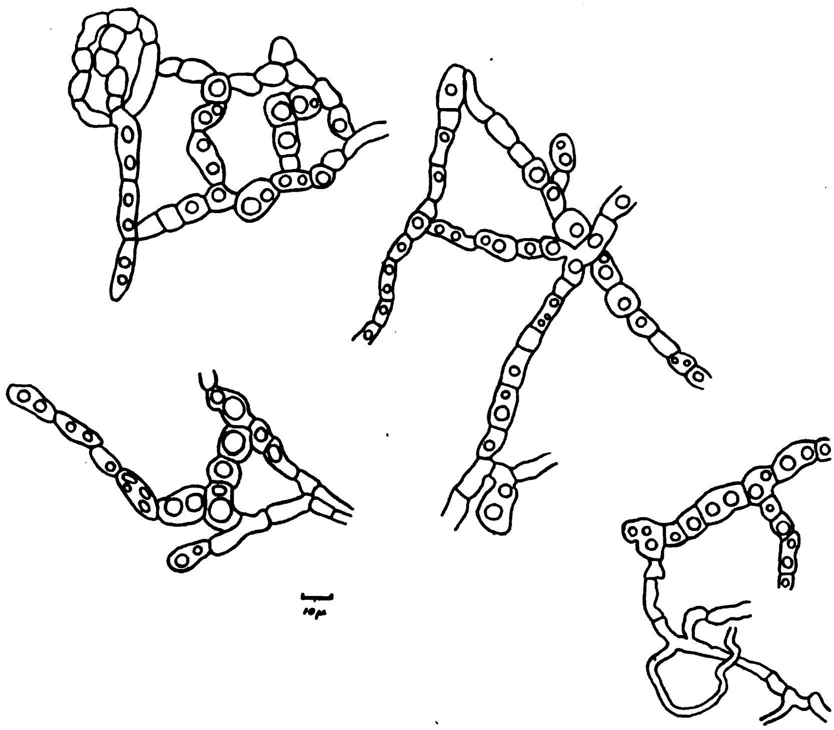


FIG. 7. MYCELIUM OF CERCOSPORA FROM AN INFECTED SEED

Note the pronounced anastomosing of the superficial hypae, the cells of which are dark colored and thick walled. These connect with hypae within the seed coat consisting of more elongated cells, of smaller diameter and hyaline in appearance.

Isolations of the organism were made as follows: the infected seeds were immersed in 95 per cent alcohol for a few seconds, in order to "wet" the surface and then transferred to a 1:1000 mercuric chloride solution for 30 seconds. This was followed by rinsing in sterile water and finally the seeds were planted on poured plates of potato dextrose agar. Almost invariably pure cultures of the fungus were obtained.

By partial drying of plate cultures of this organism abundant conidia of *Cercospora medicaginis* were obtained. This shows beyond doubt that mycelium of this fungus is borne on the seeds. The pathogenicity of the organism thus obtained was demonstrated by inoculation of healthy bur clover plants. Infection was obtained both with and without wounding of the leaves previous to inoculation.

## EXTENT OF SEED INFECTION

Two samples of seeds gathered in 1919 from the Alabama experiment station plots were examined in order to determine the percentage of seeds infected with *Cercospora medicaginis*. They were removed from the burs and sorted into three classes: (1) those badly infected, (2) those showing evidence of infection under the low power of the microscope, and (3) those apparently healthy.

TABLE 1

*Extent of seed infection*

| CLASS | LOT 1 | | LOT 2 | |
|---|---|---|---|---|
| | NO. SEEDS | PER CENT | NO. SEEDS | PER CENT |
| Macroscopic lesions......... | 71 | 19.88 | 326 | 49.02 |
| Microscopic lesions.......... | 161 | 45.09 | 163 | 24.51 |
| Apparently healthy......... | 125 | 35.03 | 176 | 26.47 |
| Total.................... | 357 | 100.00 | 665 | 100.00 |

The two samples therefore show a total infection of 65.0 per cent and 73.5 per cent respectively. Such a large percentage of seed infection is the probable explanation of the severity of the disease in the field.

The badly diseased seeds were found to be lighter in weight than the healthy ones. For example 250 badly diseased seeds weigh .5596 grams as compared with .5771 grams the weight of 250 healthy seeds. A difference of .0175 grams in favor of the latter. The difference between diseased and healthy seeds is shown very strikingly in plate XIV, fig. 4.

## CONTROL

*Clean seeds.* Before it was found that the disease was seed borne it seemed that if the burs harbored the fungus it might be controlled by removing the seeds from the burs. A sample of burs was picked free from dirt, sticks, etc., the seeds removed by hand and both the seeds and burs were weighed. It was found that the seeds constituted only 30 per cent by weight.

As purchased on the market bur clover seeds contain a considerable amount of "trash" which further reduces this percentage. It appears that clean seeds would be a matter of practical economy. Since the fungus, however, has been found to hibernate on the seeds clean seeds of themselves will not control the disease. This method must be used in connection with others.

*Boiling.* It is a general practice to boil bur clover seeds principally to hasten the germination of the seeds which have very hard impervious seed coats. The method as recommended by the Alabama Experiment Station is essentially as follows: The seeds are soaked in cold water,

immersed in boiling water for one minute and then immediately plunged back into the cold water again for the two-fold purpose of rapid cooling and reinoculation with the legume bacteria.[5]

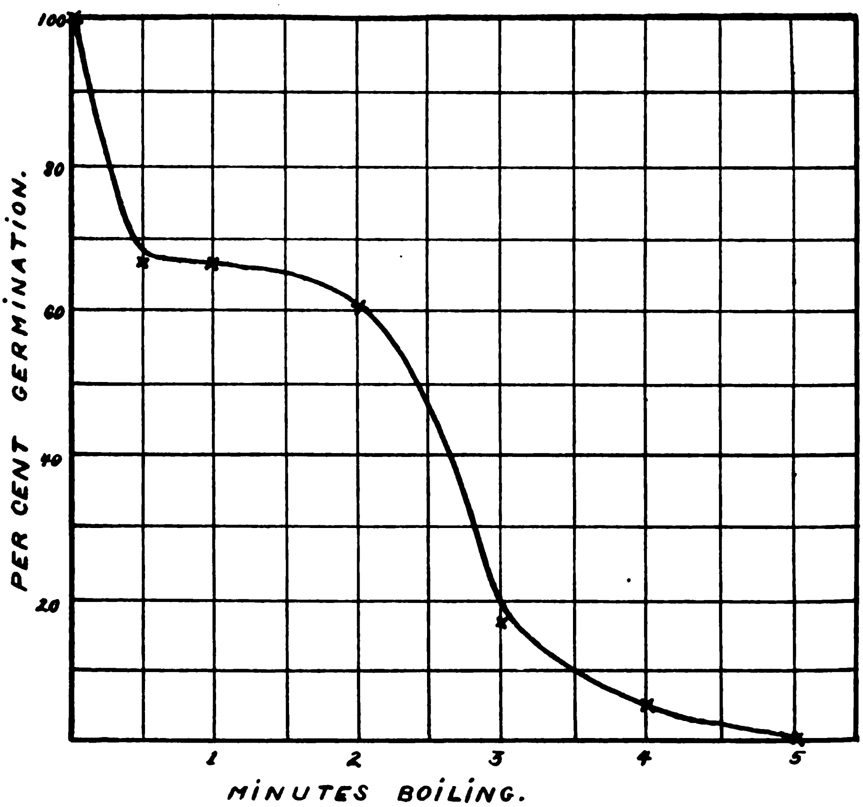



FIG .8. EFFECT OF BOILING ON THE GERMINATION OF SEEDS
Per cent of germination plotted against time in minutes of the boiling period.

A preliminary experiment to test the effect of boiling on the germination of bur clover seeds was made. Ten seeds were used in each test. The length of boiling varied from 1 minute up to 30 minutes. The seeds were placed to germinate in petri dishes on heavy filter paper moistened with tap water.

[5] Duggar, J. F. and Tisdale, H. B. Bur-clover seed: Means of hastening their germination. Alabama Agric. Exp. Sta. Cir. 29: 113–116. 1914.

TABLE 2

*Effect of boiling on seed germination*

| TIME OF BOILING MINUTES | PER CENT OF GERMINATION | |
|---|---|---|
| | NOT SOAKED | SOAKED OVER NIGHT |
| 0 | 0 | 0 |
| 1 | 50 | 70 |
| 2 | 40 | 50 |
| 3 | 60 | 30 |
| 5 | 20 | 10 |
| 10 | 0 | 0 |
| 30 | 0 | 10 |

The result for one minute is in fair agreement with those of Duggar and Tisdale (4) who obtained 51 per cent of burs with sprouted seeds without soaking and 76 per cent after soaking four hours.

Similar results were obtained using 100 seeds in each test and planting them in soil in flats.

TABLE 3

*Effect of boiling on the germination of seeds in soil*

| TIME OF BOILING MINUTES | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| PER CENT OF GERMINATION | 10 | 75 | 25 | 20 | 8 | 2 |

The writer wishes to point out an error in this type of experiment viz. the test does not show if one minute of boiling injures the seeds or not. If it is potentially able to germinate 100 per cent under the proper conditions then one minute at the boiling temperature causes considerable injury. That the boiling had made the seed coats permeable is shown by the fact that all the seeds were swollen after the treatment while those ungerminated seeds in the case of no boiling did not swell. Attention was first directed towards this matter by the use of seeds which had been put through a small cotton gin to remove the burs. These showed over 30 per cent germination without boiling. A greater reduction in germination due to boiling was noted and is probably due to the fact that in many instances the seed coats were broken. With this in mind an experiment was performed in which one lot of unboiled seeds was scarified with sandpaper.

It is evident, therefore, that boiling one minute injures the seeds to the extent of about 25 per cent. (See figure 8.) There is also delayed germination. (See figure 9.)

TABLE 4

*Germination of boiled seeds compared with scarified seeds*

| TIME OF BOILING MINUTES | PER CENT. OF GERMINATION | | |
|---|---|---|---|
| | TEST 1 | TEST 2 | TEST 3 |
| 0 (not scarified) | 2 | 0 | 0 |
| 0 (scarified) | 100 | 100 | 100 |
| ½ (not scarified) | 66 | 88 | 90 |
| 1 " " | 66 | 84 | 78 |
| 2 " " | 60 | 68 | 68 |
| 3 " " | 16 | 44 | 48 |
| 4 " " | 4 | | |
| 5 " " | 0 | | |

*The effect of boiling on the fungus.* Six badly infected seeds were surface disinfected and then immersed in sterile boiling water for varying periods of time. They were then planted on agar in petri dishes.

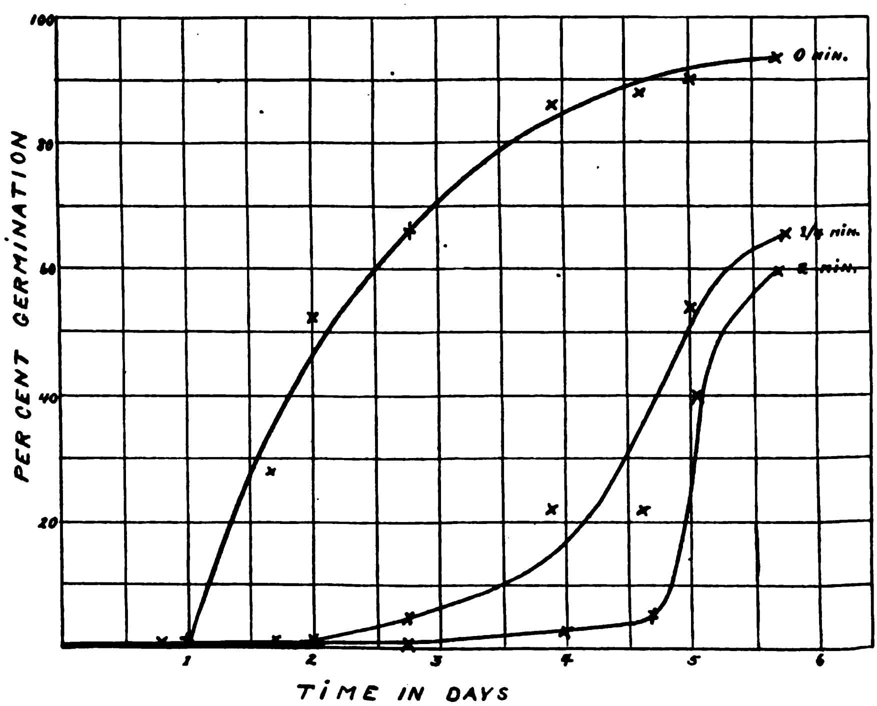
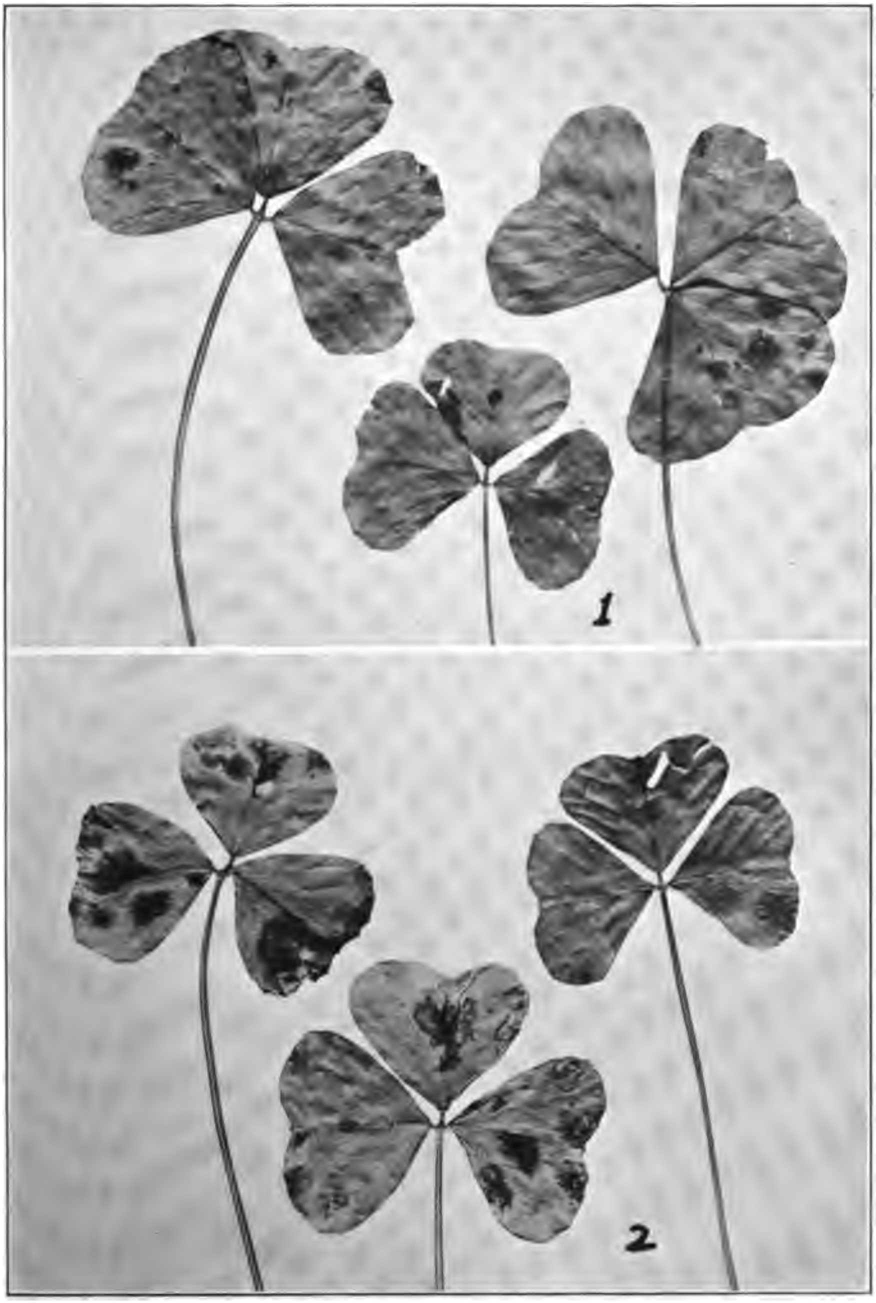


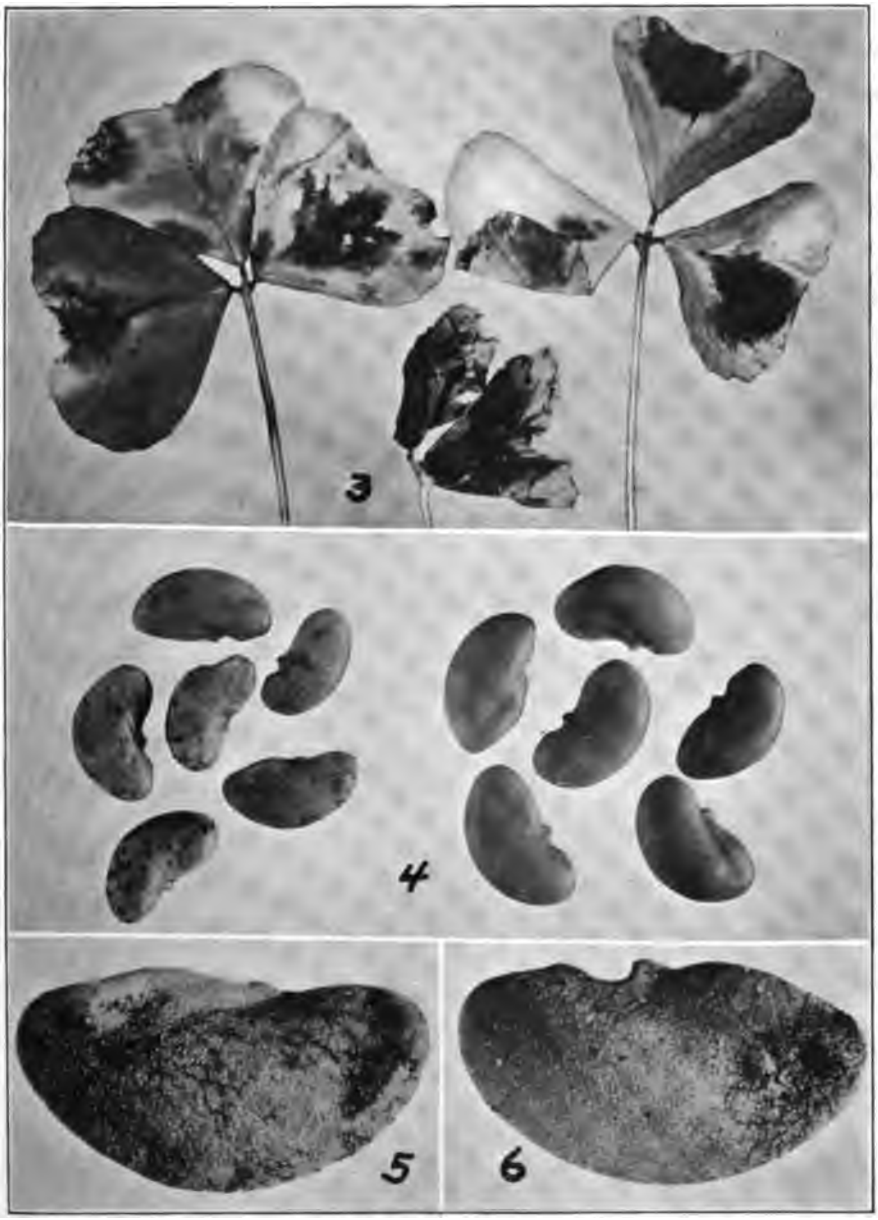

FIG. 9. EFFECT OF BOILING ON THE RATE OF GERMINATION
Per cent of germination plotted against time in days for periods of 0, ½ and two minutes boiling.




SYMPTOMS OF BUR-CLOVER LEAF-SPOT ON THE LEAVES

**Fig. 1.** An early stage of infection. Note the effect of the infection on the natural leaf marking in the centers of several of the leaflets.

**Fig. 2.** A more advanced stage of the disease. Several of the leaflets show considerable yellowing.




SYMPTOMS OF THE BUR-CLOVER LEAF-SPOT ON THE LEAVES AND SEEDS

Fig. 3. An advanced stage of infection. Note the lesion on the petiole of one of the leaves.

Fig. 4. Contrast the dark markings on the diseased seed at the left with the appearance of the healthy seed at the right. × about 6.

Fig. 5. An infected seed considerably enlarged which shows a network of mycelial strands over its surface.

Fig. 6. Sometimes the markings are more localized. Note the sclerotia-like structures formed on the mycelium.

With no boiling Cercospora grew out from the seeds while with 1, 2, 3, 4, and 5 minutes boiling no fungus growth appeared. Germination of the seeds was noted in the one minute test. This is an indication that one minute boiling is effective in killing the fungus. This was confirmed in another experiment using 5 seeds in each test. Five colonies of Cercospora were obtained without boiling and none above one-half minute at the boiling temperature.

To test the effect of boiling on the development of the disease, seeds were boiled for varying lengths of time and planted in flats in the greenhouse. One hundred seeds were planted in each flat.

TABLE 5

*The effect of boiling on the development of the disease*

| TIME OF BOILING (MINUTES) | NUMBER OF PLANTS | PER CENT. DISEASED LEAVES |
|---|---|---|
| 0 | 9 | 2.6 |
| 1 | 42 | 10.0 |
| 2 | 27 | 5.7 |
| 3 | 9 | 2.0 |

This indicates that boiling does not prevent the development of the disease and therefore agrees with the fact that in the field the disease frequently develops on plants from boiled seeds.

*Formaldehyde and mercuric chloride.* Preliminary experiments with these substances seem to show that they are effective in controlling the disease and that in concentrations one pint to thirty gallons of water and 1:1000 respectively they do not cause decreased germination after 2 hours' treatment.

*Recommendations.* The Cercospora leaf-spot disease of bur clover is seed borne and therefore in controlling it attention should be directed towards seed treatment. This is particularly important since in some cases over 70 per cent of the seeds are infected with this fungus. Heretofore the practice of boiling the burs one minute has been the only means suggested for the control of this serious disease. This is, however, ineffective under field conditions and indeed causes injury to the seeds, as evidenced by a decrease in the percentage of seeds germinating. Germination is also delayed. There is no doubt that this practice should be discontinued both from the standpoint of cultural practice and of disease control.

The writer would suggest the following procedure: 1. that seeds free of burs be used, 2. that the seeds be treated with formaldehyde solution to kill the fungus mycelium on the seed coats, 3. that the seeds be scarified, and 4. inoculated with legume bacteria.

The first point involves a problem for the agricultural engineer. The burs are very compact and the seed is not easily removed. Some progress has already been made along this line and it seems that the problem will not be difficult to solve. Although experiments are not as yet conclusive formaldehyde solution should control the disease as the mycelium is quite superficial. Thorough scarification following this treatment would then give rapid and complete germination of viable seed. Inoculation is advised, of course, unless inoculated soil is used.

## CONCLUSIONS

(1) The Cercospora leaf-spot of Southern bur-clover, caused by the fungus *Cercospora medicaginis* E. & E. which is responsible for considerable damage to this crop is carried over from one season to another by means of mycelium on the seed coats.

(2) The extent of seed infection is shown to be very large.

(3) Boiling bur-clover seed shows considerable injury to the seed as indicated by reduced and slower germination.

(4) In practice boiling the seeds does not prevent the disease.

(5) Experiments thus far indicate that the disease may be controlled by treating the seeds with formaldehyde solution.

(6) It is suggested that hulled seeds treated with formaldehyde scarified and inoculated with the legume organism will give good stands of bur clover free from the Cercospora leaf-spots.

# SOME NEW OR LITTLE KNOWN HOSTS FOR WOOD-DESTROYING FUNGI. III

Arthur S. Rhoads

In two previous articles (4, 5) the writer has emphasized the desirability of studying the wood-rotting fungi from the broader concepts of their host and ecological relationships, inasmuch as a knowledge of the host is often a valuable aid in the determination of even the wood-rotting fungi. Aside from a few species, such as *Fomes pinicola*, *Polyporus sulphureus*, and *Armillaria mellea*, which grow on coniferous or dicotyledonous wood with equal facility, the wood-rotting fungi may, from an ecological standpoint, be roughly divided into a coniferous wood association and a dicotyledonous wood association, in accordance as they grow on either one class of wood or the other with more or less regularity. Many species are so nearly constant in their habit of growth on either one or the other of these classes of wood, or even on genera of wood, that mycological workers in the past have attached great significance to this point, in fact too much. Even the wood-rotting fungi thought to be confined to a certain class, or even genus of wood have their exceptions, as critical studies of the fungi under field condition are constantly showing.

In view of our gradually increasing knowledge of the host relationships of the wood-rotting fungi the writer believes that in taxonomic work more attention should be paid to the study of the morphology of the wood-rotting fungi than to their host limitations, at least as embodied in such narrowly limited captions as are often employed as diagnostic features in keys. Not infrequently mycologists have been influenced by host relationship or geographic distribution in describing specimens of fungi as new species, when a critical study of the morphology would have assured them that the specimen in question was merely a well-known species occurring on a new host or from a quite different locality than hitherto known. Intensive field studies along these lines should imbue the taxonomic worker with a greater regard for latitude in his concept of our species, which, in the wood-destroying fungi at least, are at best but arbitrarily defined.

Inasmuch as there is more or less of a definite association of wood-rotting fungi on conifers and on hardwoods it is of interest to note the occasional departure of the fungi from their accustomed hosts. In continuance of the observations recorded in two previous papers on new

or little known hosts for wood-destroying fungi, the writer wishes to cite the following cases that have come to his attention recently. All collections cited were made personally unless otherwise noted, and are given either because of the marked departure of the fungi from their usual coniferous or dicotyledonous hosts, or of the ability of fungi ordinarily growing saprophytically, to attack the wood of living trees.

### OCCURRENCE OF WOOD-DESTROYING FUNGI ON UNUSUAL HOSTS

*Schizophyllum commune* Fries

On a windthrown trunk of *Picea rubens*, Tuckerman Ravine Trail, Mt. Washington, New Hampshire.

On a chute pole of *Abies concolor*, in abandoned log chute, Plumas National Forest, near Massack, California.

On *Sequoia sempervirens*, growing on sapwood of slab left after tie manufacture, Lagunitas, California.

*Hymenochaete tabacina* (Sow.) Lev.

On a fallen sapling of *Tsuga canadensis*. Specimens collected by Dr. L. O. Overholts and the writer at North Conway, New Hampshire.

On *Sequoia sempervirens*, growing on trunk and branches of fallen sapling, Canyon, Contra Costa Co., California.

*Stereum hirsutum* (Willd.) Fr.

On fallen branches of *Pinus radiata*, San Francisco, California.

On end of cull logs of *Libocedrus decurrens*, growing on sapwood only. Plumus National Forest, near Massack, California.

On end of cull logs of *Abies concolor*, growing on sapwood. Plumus National Forest, Massack, California.

On *Sequoia sempervirens*, growing at base of dead portion of branch of recently felled tree, Lagunitas, California.

*Hydnum ochraceum* Pers.

On *Cupressus macrocarpa*, growing on bark of fire-killed trunk in a sand-dune plantation, San Francisco, California.

*Polystictus versicolor* (L.) Fries

On *Pinus radiata*, San Francisco, California. A fine collection of large sporophores was made from the base of a fire-killed tree in a sand-dune plantation. *Polystictus abietinus* (Dicks.) Quel. was fruiting exceptionally abundantly on a large percentage of the dead Monterey pines on this and other adjacent burns.

On end of log of *Picea sitchensis*, Requa, California.

On charred stump of *Pseudotsuga taxifolia*, Plumas National Forest, near Massack, California.

On cull logs and stumps of *Abies concolor*, Plumas National Forest, near Massack, California.

On *Sequoia sempervirens*, occurring on slash left after logging, Requa, California. Also on sapling of the same species used as rail in rustic fence, Lagunitas, California.

On stumps of *Tsuga heterophylla*, Coeur d'Alene, Idaho.

Abundant on cull logs and fallen trunks of *Libocedrus decurrens*, Plumas National Forest, near Massack, California. The sporophores frequently persist beyond the first season and develop a second layer of tubes with a distinct stratified appearance. The stratification of the tubes of this species appears to be of more or less frequent occurrence.

*Polystictus hirsutus* (Wulf.) Fries

On stump of *Pseudotsuga taxifolia*. Specimen collected by Dr. J. S. Boyce at Willow Creek, Humboldt Co., California.

On dead tree of *Pinus sabiniana*. Specimens collected by Mr. C. R. Stillinger at Auburn, California. The sporophores had continued growth during the second season and were unusually thick, although the tubes were not distinctly stratified as were specimens collected on *Aesculus californica* by the writer in Marin Co., California. Sporophores of this fungus quite frequently persist for two and sometimes three seasons.

*Polystictus abietinus* (Dicks.) Quel.

On fallen trunk of *Quercus* sp. Specimen collected in Lagunitas Canyon, Marin Co., California, by Mr. Lewis S. Rose and communicated by Dr. W. A. Setchell of the University of California.

*Polyporus caesius* (Schrad.) Fries

On fallen branch of *Picea sitchensis*, Requa, California. Although of rare occurrence on coniferous wood in the Eastern United States, *Polyporus caesius* occurs quite often on coniferous wood in the humid forests of the Pacific Coast and Pacific Northwest.

*Polyporus cutifractus* Murrill

In his description of this recently published species, Murrill (2, p. 8) states that it has been collected on a much decayed fir log in a virgin forest at Newport, Oregon, and also on a maple log and trunks of *Thuya* and *Pseudotsuga* in Washington.

A fine imbricate specimen of what was determined by Dr. W. A. Murrill as this species was collected by the writer on a living and apparently uninjured tree of *Cupressus macrocarpa* on the campus of Leland Stanford University, California. The specimen occurred about two feet above the base in a depression between two fluted portions. Additional specimens of this fungus have been observed growing in a similar manner on living *Cupressus macrocarpa* trees on the campus of the University of California. It also occurs here on felled trunks of the same species.

The above collections will extend the range of this little known species, and add to its hitherto known hosts and habit of growth.

*Polyporus carbonarius* Murrill

Specimens collected by the writer at San Francisco, California, on *Cupressus macrocarpa* logs used to retain an earth fill, were determined by Dr. W. A. Murrill as representing the normal form of his recently published species, *Tyromyces carbonarius*, which he states was described from specimens that were sodden and quite abnormal on the upper surface. In his description, Murrill (2, p. 8) states that the specimens were collected on a burned red fir log at Seattle, Washington. The writer has made a second collection of the same plant on a *Cupressus macrocarpa* stump, and two others on *Pinus radiata*, one being on a stump and the other on a fallen trunk. All three collections were made in forest plantations in San Francisco, California. These collections extend the hitherto known range and hosts for this species, which also is little known. None of these four specimens, which were collected in an actively growing state, showed any indication of a faint rosy hue to the hymenium, which Murrill (2, p. 9) mentions as being quite characteristic. Neither did the tubes display any irregularity, with long dissepiments suggesting *Irpiciporus* as Murrill states, in his description (p. 8), may occur at times. The writer's specimens also differ from Murrill's description in that the pore mouths, instead of being "subcircular, 4 to a mm., not glistening," are distinctly angular, and minute, varying from 4–5 to a mm., and with a distinct sheen to the pore mouths in normally developed specimens.

*Polyporus leucospongia* Cooke & Hark.

On piece of fallen sapling of *Populus tremuloides*, Plumas National Forest, near Massack, California.

*Polyporus dichrous* Fries

On fallen trunk of *Pinus radiata*, Pebble Beach, Monterey Peninsula, California. Specimen collected by Dr. E. P. Meinecke.

*Polyporus picipes* Fries

On log of *Abies balsamea*, Willey House, New Hampshire. Specimen collected by Dr. L. O. Overholts and the writer.

*Polyporus Berkeleyi* Fries

On *Picea sitchensis*, growing on roots of living tree, Requa, California. In the central and eastern United States this fungus is usually found on oaks; along the Pacific Coast and in the northwestern United States it usually grows on conifers.

*Polyporus nidulans* Fries

On dead tree of *Tsuga canadensis*. Specimen collected at Ormstown, Quebec, Canada, by Prof. R. J. Blair (No. 144) and communicated by Dr. L. O. Overholts (Herb. L. O. Overholts, No. 4084).

*Polyporus Schweinitzii* Fries

On charred stump of *Eucalyptus globulus* in a pure plantation of that species, San Francisco, California. A single small stipitate specimen was found growing out of the top of a stump about which a fire had been built.

To the best of the writer's knowledge this is the first report in this country of the growth of *Polyporus Schweinitzii* on dicotyledonous wood. This specimen is of unusual interest by reason of its occurrence on wood of an exotic tree. Both the eucalypts and acacias, now so extensively planted in California, are quite susceptible to a number of our common wood-rotting fungi.

*Polyporus dryadeus* (Pers.) Fries

On *Abies concolor*, Trinity National Forest, California. While working over the collections of forest tree fungi in the San Francisco office of Forest Pathology, the writer found an undetermined collection of this species on *Abies concolor*. Whether the sporophores were growing on a living or dead tree is not known, but the orientation of the sporophore with regard to the attached bark testifies that the tree was erect, and the appearance of the bark, that it probably was living.

On *Abies grandis*, the sporophores occurring from 1½–2 feet above the ground-level on a living tree 48 inches in diameter, and causing a saprot. Specimens collected by Dr. J. S. Boyce at Randle, Lewis Co.,

Washington. Recent reports indicate that this fungus is not so rare on coniferous trees as was formerly supposed.

Long (1, p. 247) mentions three collections of *Polyporus dryadeus* on *Tsuga heterophylla* from widely separated parts of the State of Washington, which were collected by Dr. C. J. Humphrey with the statement that the sporophores were attached to the host at or near the surface of the ground and that the plant is a true parasite and kills the tree as it attacks. Murrill (3, p. 41) refers to the same collections of this fungus on *Tsuga heterophylla* and states that he has it from Oregon on this host and on *Abies grandis*. Recently Weir (6) states that *Polyporus dryadeus* occurs most frequently on *Tsuga heterophylla* and *T. mertensiana* and that it has also been collected on *Abies grandis* and *Picea Engelmanni*. The occurrence of this fungus on coniferous hosts is now known from California, Oregon, Washington, Idaho, and Montana.

*Fomes Meliae* (Underw.) Murrill

On *Ginkgo biloba*, Washington, District of Columbia. The sporophores collected were growing on the margin of dead wood left after sawing off a large limb, occurring just in advance of the callus formation. This collection was made in the fall of 1918. One year previous to this the writer's attention was directed to sporophores of *Polystictus hirsutus* (Wulf.) Fries growing on the same area of dead wood (5). *Fomes Meliae* rarely departs from the genera, *Fraxinus*, *Gleditsia*, and *Melia*.

*Fomes applanatus* (Pers.) Wallr.

On stump of *Tsuga heterophylla*, near Orick, Humboldt Co., California.

On fallen trunk of *Picea sitchensis*, Requa, California.

On fallen trunk of *Pseudotsuga taxifolia*, Requa, California.

On fallen trunks of *Abies concolor*, Plumas National Forest, near Cascade, California. In the central and eastern United States *Fomes applanatus* almost always occurs on dicotyledonous wood; in the West, however, its occurrence on coniferous wood is fairly common in the humid regions.

*Lenzites saepiaria* (Wulf.) Fries

On *Alnus incana*, growing on a wounded living tree which showed the characteristic rot of this fungus. Specimen collected in Reitz Gap, Center Co., Pennsylvania, and communicated by Dr. L. O. Overholts (Herb. L. O. Overholts, No. 3444).

On piece of *Populus tremuloides* trunk, producing the characteristic decay of this fungus, Plumas National Forest, near Massack, California.

This species and its characteristic rot have also been collected on a fallen sapling of the same host at Spokane, Washington.

The decay caused by this fungus on hardwoods can not be distinguished from that caused by the closely related species, *L. trabea*, which commonly occurs on hardwoods.

UNUSUAL OCCURRENCE OF NORMALLY SAPROPHYTIC WOOD-DESTROYING FUNGI AS WOUND FUNGI ON LIVING TREES

Among the wood-rotting fungi are several that normally occur as saprophytes, but, under certain conditions, sometimes attack the wood of living trees after gaining entrance to them through wounds of various kinds. The following instances, based upon the writer's field collections, are cited as exemplifying the ability of normally saprophytic wood-inhabiting fungi to assume the role of a wound fungus.

*Schizophyllum commune* Fries frequently attains a luxuriant growth on street, ornamental, and fruit trees, after establishing itself in dead areas induced by wounds in living trees. The occurrence of this fungus as a wound fungus has been noted on *Rhus hirta* in New York, Pennsylvania, Maryland, Virginia, and District of Columbia; on *Rhux vernix* in Massachusetts; on *Acer rubrum* in Pennsylvania; on *Acer saccharum* and *Cedrela sinensis* in New York (the latter collection by Mr. G. F. Gravatt); on *Acer platanoides* in the District of Columbia; on *Ceanothus thrysiflorus*, *Acacia melanoxylon*, and other species of *Acacia* in California.

*Polystictus hirsutus* (Wulf.) Fries has been observed as a wound parasite on a vigorously growing ornamental cherry (*Prunus* sp.) tree at Spokane, Washington.

*Polyporus gilvus* (Schw.) Fries likewise occurs on living forest and street trees injured in various ways. Its occurrence in this manner has been noted on *Quercus coccinea* and *Acer saccharinum* in Pennsylvania, on *Platanus occidentalis* in Pennsylvania and the District of Columbia, and was recently reported by the writer (4) as occurring as a wound parasite on *Rhus toxicodendron* in Maryland.

*Fomes applanatus* (Pers.) Wallr. frequently assumes the role of a facultative parasite, attacking not only older trees in which the vitality has become considerably lowered, but also younger trees making a vigorous growth. White (7), who recently has made a comprehensive study of this species, definitely proves that it may occur as a true wound parasite. He states that it is very destructive in southern Ontario and gives a list of the living species known to be attacked. Its occurrence as a root parasite on aspens has commonly been observed in various sections of this country. In addition the writer has observed its occurrence as a wound parasite in the following instances: on *Quercus*

*alba* in Pennsylvania; on *Quercus rubra* in New Hampshire; on *Fagus atropunicea* in Maine; on *Eucalyptus globulus*, *Crataegus* sp., *Acacia* sp., *Umbellularia californica*, *Schinus molle*, and *Quercus agrifolia* in California. In the three last named species *Fomes applanatus* causes a very destructive heart rot.

*Fomes pinicola* (Sw.) Cooke, which is of comparatively rare occurrence on living trees, was noted growing out of an open fire scar on a small suppressed, living sapling of *Abies concolor* on the Plumas National Forest, near Massack, California. A specimen in the San Francisco office collected by Dr. E. P. Meinecke on the Stanislaus National Forest in California, grew out of a fire scar on a good sized living tree of *Pinus lambertiana*, causing an extensive rot of the heartwood. The occurrence of *Fomes pinicola* has also been noted on a living tree of *Pseudotsuga taxifolia* at Spokane, Washington. In this case three sporophores occurred near the ground-level, one on each of three sides of the base, where the bark had been killed by fire.

*Fomes roseus* (Alb. & Schw.) Cke. has been observed in Humboldt Co., California, causing a destructive heartrot in living trees of *Pseudotsuga taxifolia*.

*Trametes suaveolens* (L.) Fries and *Daedalea unicolor* (Bull.) Fries have been observed attacking living trunks of *Salix* sp. in Maine.

The writer takes this occasion to correct an error in the identity of a fungus in the first paper of this series (4). The specimen of *Coriolellus sepium* (=*Trametes sepium*) cited on a stump of *Tsuga canadensis* (p. 47) proves to be the extremely variable *Trametes heteromorpha* Fries, a species then but poorly understood in this country.

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# EUGENE WASHBURN ROARK

L. R. Jones and G. W. Keitt

Eugene Washburn Roark was born at Lexington, Ky., Sept. 5, 1894, and died at Minneapolis, Minn., Oct. 14, 1918. He spent his early youth at Lexington, where his father occupied the chair of education in the University of Kentucky. He received his early education in the schools of Lexington and Richmond, from which he went to Clark College, where he was granted the degree of Bachelor of Arts in 1914. Throughout his undergraduate training he continued to develop the naturalistic bent of his earlier youth and turned to the biological courses in anticipation of later specializing in plant pathology. In 1914 he entered the University of Wisconsin as a graduate student in plant pathology. His first research work comprised a very creditable study of certain aspects of the relations of *Phytophthora infestans* to the potato and the tomato. The results of these studies were presented as a thesis for the degree of Master of Science in 1915. From 1915 to 1917 he served as assistant in the Department of Plant Pathology and in 1918 he was awarded a fellowship in this department. Throughout this period, he rendered faithful services of the highest quality, particularly in relation to the fruit disease courses and investigations of the department. At the same time, he prosecuted his own studies and research work with vigor and success.

The entrance of the United States into the war brought responsibilities which Roark met unflinchingly, and in the fulfillment of which he later gave his life. While awaiting his call to the colors, he carried the entire burden of the fruit disease work of the department, in the absence of the other members of that section of the staff, and at the same time completed the work for his doctorate, which was conferred in June, 1918. His doctor's thesis was a highly creditable dissertation on "The Septoria Leaf Spot of Rubus." On Sept. 3, before he had been able to finish preparing his thesis for publication, he responded to his call to the colors and entered the Naval Aviation Service at Minneapolis. After a brief period of training, he contracted influenza which rapidly developed into pneumonia, to which he succumbed on Oct. 14, 1918.

Dr. Roark combined in a rare way the characteristics of the sincere friend, the courteous gentleman and the scholarly scientist. The keen sense of personal loss on the part of his university associates is tempered only by the realization that he entered his country's service with deliberation and devotion, ready to give without stint of his splendid young manhood, and it remains their privilege thus to continue to share in some small degree in his supreme sacrifice.

# THE SEPTORIA LEAF SPOT OF RUBUS

E. W. Roark[1]

The fungus formerly known as *Septoria rubi* Westendorp causes leaf spots on many species of Rubus (blackberries and raspberries) and attacks the stems of some of these species. The disease occurs throughout Europe and North America. In the United States it has been reported from all but seven states, and is present in all sections where the hosts are grown to any considerable extent.

Wherever found, it is usually quite common but rarely serious. It cannot be considered a major disease of bramble fruits. The chief damage done is brought about by early defoliation, which inhibits normal bud development and predisposes the canes to winter injury.

The leaf spots vary in appearance on different hosts but at maturity usually show light colored centers with brownish or reddish borders. The pathogene also causes inconspicuous lesions on the petioles and canes of some hosts.

The leaf spot fungus was named *Septoria rubi* by Westendorp about 1850. This name was antedated by the possible synonyms, *Ascochyta rubi* Laschin 1832 and *Ascochyta ruborum* Libert in 1834, but as the identity of the forms thus named has not been definitely proved, it seems advisable, for the present, to retain Westendorp as authority for the species name.

The ascigerous stage, first found in 1917 in Wisconsin, is a species of Mycosphaerella which in its morphology does not agree with any published descriptions of fungi occurring on Rubus. It seems necessary, therefore, to describe it as a new species.

Proof of the relation between the imperfect and the perfect form is based on: 1. constant association of the two in the locality where peri-

[1] When Dr. Roark responded to his call to military service, he had completed the preliminary draft of his doctor's dissertation and had prepared an abstract which was filed with the university authorities for publication in the event of his being unable to complete the preparation of his paper. The fuller paper was so nearly ready for release and was so meritorious that publication of this abstract has been postponed in the hope that the original paper might yet be edited and published. This has not been feasible, due to the fact that the plates and certain other important sections of the paper have not been found since Dr. Roark's death. It is supposed that, working under extreme pressure, he took some of his material with him for the final touches when he went into the service, and that due to his sudden and untimely death, he was unable to leave the necessary directions for its disposition. Under these circumstances, his abstract is being published, and the available parts of the original paper are being placed on file in the university library.—G. W. Keitt.

thecia have been found, 2. cellular connection of perithecia and pycnidia on the same dead leaf; 3. similar behavior of ascospores and pycnospores in germination, and similarity of the two in pure culture; 4. positive results from inoculations with spores from the ascigerous stage.

Pycnidia formed in spots on green leaves vary from typically well formed pycnidia to thin walled, imperfectly formed fruiting bodies which approach the acervulus in structure. Pycnidia formed on dead leaves are thick walled, closely grouped, and arise from heavy stromateoid masses of mycelium. It has seemed best in the discussion of these pycnidial forms to designate them, respectively, as summer pycnidia and winter pycnidia.

After a study of perithecia from the different hosts the perfect stage is described as follows:

**Mycosphaerella rubi** n. sp. Perithecia mainly hypophyllous, sometimes amphigenous, usually gregarious, erumpent, globose, 60–80$\mu$ in transverse diameter with a short papilliform ostiole, black, walls pseudoparenchymatous, two or three cell layers thick, aparaphysate; asci subclavate to cylindrical, eight-spored, very short pedicellate, 42–45 by 8–10$\mu$ in water; ascospores hyaline, slenderly fusiform, of two equal cells, straight or slightly curved, very slightly constricted at septum, 20–25 by 3.50–4.25$\mu$, extreme limits in length 17–28$\mu$, sometimes tending to occur in fours in the ascus, usually irregularly biseriate. Conidial stage: *Septoria rubi* Westendorp. Hab. on fallen leaves of *Rubus strigosus*, *R. parviflorus*, *R. allegheniensis* and *R. hispidus* in Door County, Wisconsin.

In studies of the germination of pycnospores and ascospores it was found that they readily germinate in water and nutrient solutions and that pycnospores reflect strain differences in their variable behavior in germination. Some pycnospores and ascospores have shown a definite reaction to strong, diffused sunlight, the developing germ tubes exhibiting negative heliotropism.

The minimal temperature for germination in water or in a favorable nutritive medium is slightly below 2° C.; the optimal, between 18° and 26°, about 23°; and the maximal, about 32° or slightly above.

About fifty strains of the fungus have been carried in pure culture, isolations having been made at different times of the year from the leaves and canes of various host species. Strains from the same or different hosts varied considerably in regard to type and amount of spore production, and in stromatic development, some readily forming pycnidia, while others formed only masses of needle-shaped secondary conidia. When grown on about thirty media, the fungus showed only minor variations, except that Lima bean agar was found to favor the production of secondary conidia even in case the fungus was usually stromatic.

The minimal temperature for growth on a nutrient substratum, potato agar, is less than 2°C., the optimal, between 20° and 23°; and the maximal, about 32°.

It is believed that the production of secondary conidia is primarily a strain characteristic varying greatly with different strains, but that within a given strain it can be encouraged to a certain extent by crowding of spores at the time of germination, frequent transferring, use of special media, and optimal temperature for growth.

The stromateoid type of pure-culture growth will live for several months at room temperature (about 22° to 25°C.); but, at the same temperature, cultures consisting of masses of secondary conidia lose their viability within about two weeks.

The results of many inoculations with spores derived from both pycnidia and perithecia may be briefly stated as follows: 1. spores from the ascigerous stage were found to produce leaf infection, resulting in lesions which sometimes contained typical pycnidia but usually imperfectly formed fruiting bodies; 2. the stem form of the fungus was proved to be identical with the leaf form; 3. blackberry strains would not cross to raspberries, nor would the raspberry strains infect blackberries. Conclusions were drawn from no inoculations except those which were adequately controlled by uninoculated plants and from which successful reisolations were made.

The fungus commonly overwinters as mycelium and immature pycnidia in dead leaves and, in the case of red raspberries, in the bark on canes. Perithecia are a factor in the overwintering, but are restricted in occurrence.

In Wisconsin, leaf spots usually begin to appear two or three weeks after the leaves are well opened and continue to increase in number until frost, the amount of infection depending primarily upon weather conditions.

Primary infection is brought about mainly by newly formed pycnospores from overwintering pycnidia on dead leaves or bark, though ascospores may also function in this way. Secondary infection throughout the season is caused by pycnospores from the current-season lesions.

Mature ascospores can be found late in May, and continue to develop well into July—occurring most abundantly during June. Pycnidia are formed in practically all lesions, their frequency depending somewhat upon the host variety. Viable pycnospores can be found throughout the year but are more abundant at certain times. This is due to the fact that there are usually so-called waves of infection which are correated with periods of rainfall.

The period of incubation for the fungus in leaves was found to vary from 8 to 11 days in most inoculation experiments, although wider variations sometimes occurred. From observations it would seem that in nature the incubation period may show even greater variations.

Field infection is favored by moderately cool weather and frequent periods of rainfall.

As a result of observations and experiments, it is believed that the disease is spread into cultivated plantations primarily by diseased nursery stock, the fungus being carried in the bark or persistent leaves. The principal agents of spore dissemination are wind in case of the ascospores, which are forcibly discharged into the air, and splashing or wind-borne rain in case of pycnospores, which exude in masses and can be scattered only after being separated in water.

Among the host species and varieties observed by the writer, the dewberries and smooth-leafed blackberries have shown the greatest amount of spotting, while certain black raspberries and *R. odoratus* have been least affected. These differences have not been explained.

The following tentative suggestions for controlling the disease are based primarily upon the work of others, coupled with the writer's observational evidence.

1. Care should be taken to obtain disease-free plants for setting out new plantations.

2. Sources of inoculum should be reduced by destruction of dead leaves and old canes in the fall.

3. When conditions for the development of leaf spot are favorable, spray with Bordeaux mixture, 3–3–50, after the leaf buds are well opened, and at intervals of two or three weeks until the fruit is two-thirds grown.

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# BRIEFER ARTICLES

## FIJI DISEASE OF SUGAR CANE IN THE PHILIPPINE ISLANDS

OTTO A. REINKING

WITH PLATES XV AND XVI

The Fiji disease of sugar cane has been present in the Philippine Islands for some years. It has been identified as such in sugar cane fields on the Island of Mindoro and about Calamba on the Island of Luzon, and undoubtedly is present in other sugar cane sections. It has been present in the Philippines at least as far back as July, 1916, but no authenticated report of its presence was given until the writer had an opportunity to make an investigation of the diseased fields in December, 1920. The disease has been extremely destructive, especially to foreign varieties of cane such as Java 247 and Hawaii 109. Losses of from fifty to seventy-five per cent have occurred in heavily infected fields. In the infested regions it has spread rapidly from one plantation to another through the use of infected tops for planting. Certain Philippine sugar canes are not so severely affected and little damage is done where these varieties are grown. The use of these canes on plantations in the Philippines, along with crop rotation, appears to be an effective method of control.

### SYMPTOMS OF THE DISEASE

Badly affected plants, due to the shortening of the internodes, are small, stunted, and have a bunchy growth of leaves produced at the top (Plate XV, figs. A and B). An excessive number of shoots is developed, and the leaves produced are small and slender. The leaves of such plants are a darker green than normal and usually are more upright and slender. The darker green is present even on plant sugar cane that has been affected apparently only for a few months. Otherwise, in the latter cases, the appearance of the sugar cane is normal except for a slight stunting, the more upright leaves, and the production of galls. Galls are almost always present on the leaves of diseased plants.

In young and old cases of disease, galls are produced on the leaves. On young cases of infection, in which the leaves are almost normal, being natural in size, but a darker green, the galls, in all stages, may be well developed. They are characterized by raised elongated blisters produced on the under surface of the leaf, either on the main vein or on the smaller veins (Plate XVI, figs. A, B, C). They extend lengthwise of the leaf. The galls in such cases are from two millimeters to six


FIJI DISEASE OF SUGAR CANE

Fig. A. Bunchy top and excessive number of shoots caused by this disease.
Fig. B. Stunted tops with small, slender leaves.

or more centimeters long. The young galls are a lighter green than the leaf. If a diseased leaf is held up to the sun, the galls are indicated by a translucence of the affected parts. The majority of the galls are present on the lower portions of the leaf blade down near the leaf sheath. They may, however, extend out to the tips of the leaves and form upon the young green leaves even before they have unrolled (Plate XVI fig. A).

In advanced cases the galls are usually produced in greater abundance on the leaf blade, but may also be found on the leaf sheath. No galls have been observed on the stem of the cane nor do they extend through the leaf. There is a slight yellowing on the upper surface of the leaf above the gall. At first the galls are light green, but later become much thickened, opaque, frequently turn reddish in spots, then brownish, and in such cases they may burst open exposing a brownish mass (Pl. XVI, fig.C). The galls are present in abundance on old dead and dried leaves and these may be a source of infection. Galls on dead leaves usually are not ruptured.

In diseased, plant sugar cane, the root system is abnormal, being small, bunchy, and slightly rotted. On ratoon, diseased canes the root system is smaller and more decayed. A rot may extend from the dead roots into the stems.

New shoots arising from the bases of such diseased plants often have a yellow streak running down the central group of unfolded leaves. In advanced cases these shoots may be rotted and the diseased condition may extend for a short distance into the stem. In the earliest stages the shoot rot is characterized by a yellowing of the exposed leaves and later by a reddening of the young rolled-up leaves within the sheaths. The leaves finally die and the entire inner part of the shoot is affected with a brown soft rot. A bad odor is present in these advanced cases. The small shoots developing from the base of a badly diseased, ratoon sugar cane are generally diseased. Frequently in such advanced cases the diseased leaves are distorted and much wrinkled. A rot is not always associated with this disease. When present it appears to be a secondary trouble caused by some other organism that attacks the weakened canes. Usually there is no discoloration of the interior of the canes of diseased plants except at the nodes where a shoot arises and just above the root system. At these points a yellowing or reddening may be present.

Instances have been observed in which the entire cane from the roots to the top is somewhat pithy and soft. No discoloration or decay was observed in these cases. The tops of such plants are very bunchy and numerous galls are produced on the leaves. This characteristic of the pithy center apparently is not general, as it was only noticed in a few

cases. Frequently in plant sugar cane, one stool of a plant is visibly diseased and the rest appear to be free from disease. It is reported, however, that tops taken from any stool of such a plant will develop the disease.

Plasmodia-like bodies appear to be present in old and young galls. These bodies are light colored in the young, and brownish and more granular in the older galls. These bodies are also present in the cells of the young shoots that arise from the base of the diseased plants. Questionable fungous bodies are present in the rotted roots and base of the stem. The presence of the fungal bodies would indicate that a fungus is responsible for the disease. It will be first necessary to conduct isolation and inoculation experiments before this can be definitely settled. At present, from all indications, it appears that the causal factor gains entrance to the plant through the root system, and that it may remain in the soil for at least one year.

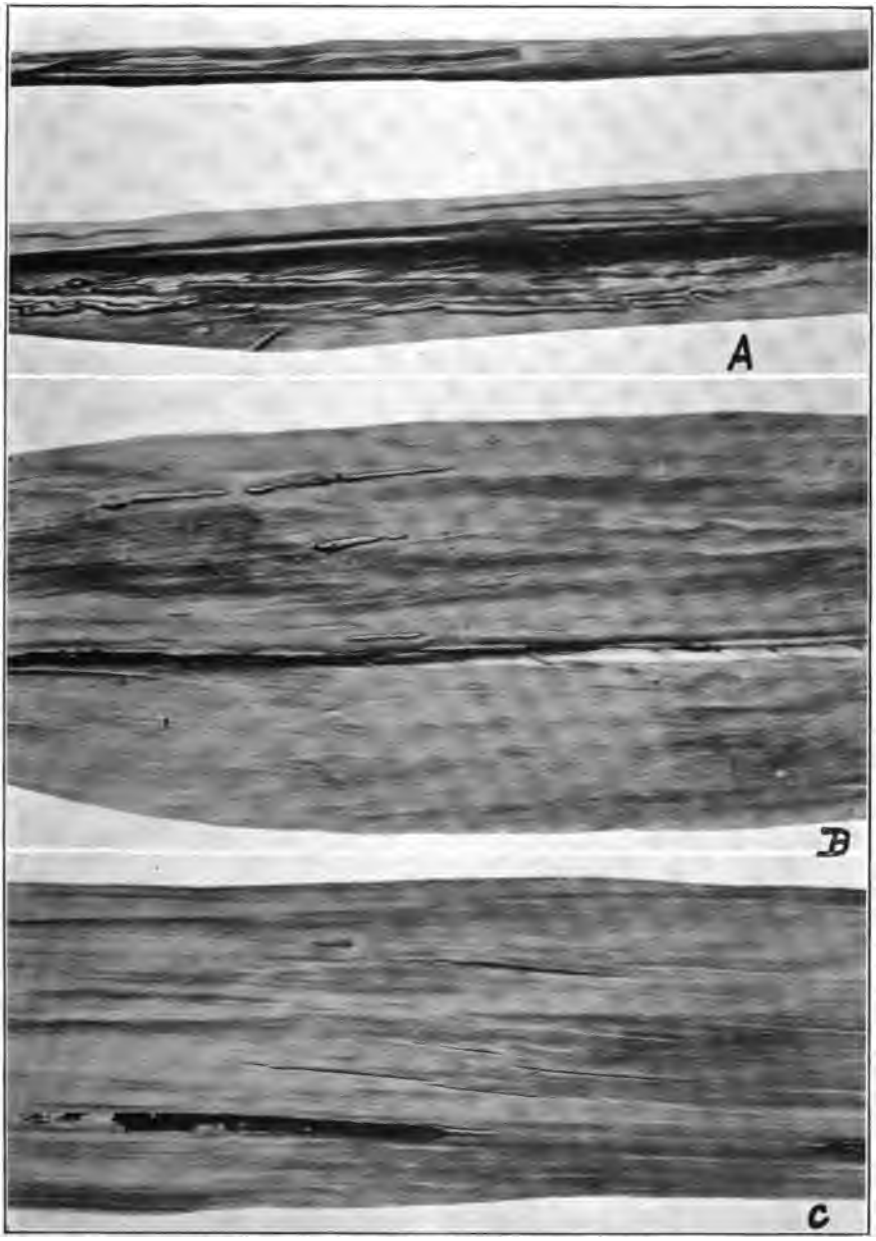
TABLE 1

*Observed susceptibility of the varieties of sugar cane to the Fiji disease*

| FOREIGN VARIETIES OF SUGAR CANE | | PHILIPPINE VARIETIES OF SUGAR CANE | |
|---|---|---|---|
| Demerara 152 | —No disease seen. | Cebu Purple | —No disease seen. |
| Demerara 247 | —Diseased. | Lamao White | — " " " |
| Demerara 604 | — " | Luzon White | —Diseased medium. |
| Demerara 625 | — " severely. | Negros Purple | — " slightly; sporadic. |
| Demerara 1135 | — " | | |
| Hawaii 16 | — " | | |
| Hawaii 20 | — " | | |
| Hawaii 27 | — " | | |
| Hawaii 69 | — " | | |
| Hawaii 109 | — " severely. | | |
| Hawaii 146 | — " | | |
| Hawaii 227 | — " | | |
| Hawaii 309 | — " | | |
| Java 100 | —No disease seen. | | |
| Java 213 | — " " " | | |
| Java 247 | —Diseased severely. | | |
| Java 826 | —No disease seen. | | |
| Lahaina | —Diseased. | | |
| Striped Mexican | — " | | |
| Yellow Caledonia | — " medium. | | |

FIELD OBSERVATIONS

The disease does not seem to show any difference in severity on plants growing on various types of soil. The infection in fields of Java 247 and Hawaiian varieties is severe both on heavy clay soils and on lighter loam soils. The disease is always more serious on the ratoon sugar




LEAF GALLS CAUSED BY FIJI DISEASE

Fig. A. Early stage of gall formation in leaves still rolled at the growing tip of the cane.

Fig. B. Galls before breaking open.

Fig. C. Galls broken open.

cane than on the plant sugar cane. Cases, however, are known where the disease is bad on plant sugar cane that is about ready to be cut. In these cases the plants are stunted and numerous galls are produced on the leaves. The chief danger in such fields is that the tops are cut for seed, and consequently the disease is widely spread throughout the plantation. Ratoon sugar cane from seriously infected, plant sugar cane may show losses of from fifty to seventy-five per cent in localized areas.

Up to date, all Philippine varieties are not severely affected. Many instances were observed where Hawaii 109 and Java 247 were planted together with the Negros Purple. Even when the severely infected Hawaiian or Javan varieties were growing intermingled with Philippine sugar cane, the infection on the latter was not severe. Negros Purple is attacked, but the disease does not appear to be so severe as on the foreign varieties. Table 1 gives a list of the different varieties of sugar cane examined, and indicates those varieties that were found to be affected.

No Fiji disease was observed on talahib, the wild sugar cane (*Saccharum spontaneum*).

Further observations may prove that the Java and Demerara varieties enumerated as being free will contract the disease. The Philippine sugar cane, however, in all instances thus far has shown marked resistance, but further investigation may prove that it is more severely attacked.

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## FALLING FOLLIAGE

MEL T. COOK[1]

Many inquiries concerning the falling of the foliage of both shade and fruit trees coming to the writer every year has led to field studies to determine the causes. These studies have been continued over a period of several years and are in the nature of observation rather than experiments. There were many more inquiries during the spring and summer of 1919 than usual and the number of varieties of trees affected much greater than usual. Therefore, the opportunities for study much greater than on previous or succeeding years. It is very evident that there are many factors which cause the falling of tree foliage. They will be taken up separately.

[1] Technical paper No. 27 of the New Jersey Agricultural Experiment Stations, Department of Plant Pathology.

### LOW TEMPERATURE

This may be the cause of the falling of foliage, even though the temperature is not low enough to cause frost. The character and extent of the injury appears to vary with the age or stage of development of the foliage. It is well known that trees standing side by side do not necessarily develop their foliage with the same degree of rapidity which no doubt explains the variation of foliage injury.

Among the most susceptible trees are the apple and the beech. Many apple leaves turn yellow before falling but some fall which are almost green. This falling is most noticeable until the leaves have reached their full size, which may be some time after the period of low temperature. The growers having forgotten the period of low temperature very naturally look for some other explanation. The explanations most generally given are fungus or spray injury. The first can usually be eliminated because at this time the foliage fungi of the apple are not well advanced and few or no spots are visible. The second factor frequently requires careful consideration, especially if the trees have beet sprayed with mixtures containing copper compounds. Many cases of this kind came to the writer's attention in 1919 and were traced to low temperature as the causal factor.

The young foliage of the beech is especially susceptible to low temperatures. The leaves show a peculiar burning or drying along the margins and frequently between the veins. In severe cases the leaves fall in great numbers and occasionally the trees are almost defoliated. In other cases leaves with brown areas may persist throughout the season. Trees standing very close together frequently show great variations in injury due to different stages of development at the time of low temperature. The injury is apparently due to the low temperature, soon after the buds open and before the leaves have reached full size and at a time when the protoplasmic activity must be very high and the cuticle very poorly developed. Some cells may be killed and others injured in different degrees; the dead cells becoming brown, the others growing and often producing more or less irregular leaves.

### SUN SCALD AND DROUTH

The soft and sugar maples are especially susceptible to sun scald and drouth injuries although other trees are often effected. It is most common on trees planted along streets or in other places where the water supply is greatly reduced because of pavements or where the heat is reflected from pavements. Trees on lawns where the soil is usually very hard or on slopes which allow the water to run off rapidly, instead of soaking into the ground are also subject to injury. The leaves first

show a streaking between the veins, very often the entire areas between the veins are affected, the entire leaf may become yellow, or irregular blotches may be formed. Norway maples are less susceptible than the soft and sugar maples, but sometimes have the appearance of being scorched. The foliage of the red maples is sometimes spotted with yellowish blotches.

This may be classed as a physiological disease due to a lack of balance between the amount of water taken in by the roots and the amount given off by the leaves. It can be corrected by heavy pruning. Trees growing under the conditions referred to should have 25 per cent or more of the branches removed every year. This treatment has been practiced by the writer with most satisfactory results.

Injuries of this kind are sometimes due to heat reflected from pavements or walls and may be classed as *sun scalds*. Injuries due to fumes, smoke or dust may be confused with those due to drouth or intense heat. These injuries are not necessarily accompanied by a falling of the leaves.

### WEAK TREES

Trees which are weak for want of suitable soil, plant food, water, or insect injuries are very likely to lose foliage in mid summer.

### SPRAY INJURIES

Spray mixtures which are improperly made or improperly applied will frequently cause severe injuries and the falling of leaves. Unfortunately we do not know much about the action of these mixtures on shade and ornamental trees. A few years ago the writer's attention was called to a very puzzling case of the falling of shade tree and peach tree leaves. An investigation proved it to be due to Paris green dust which had drifted in from the adjoining potato fields at the time of application. The leaves were falling in great numbers and the new wood showed unmistakable evidence of injury. The first row of trees in adjoining peach orchards showed severe injury and the succeeding rows showed relatively less. The wild cherry growing along the fence rows also showed very pronounced injuries on both leaves and new growths.

Arsenate of lead and lime sulfur are common causes of foliage injuries but are not necessarily accompanied by a falling of the foliage. Spray mixtures containing sulphate of copper when applied to fruit trees are very likely to be followed by a falling of the foliage.

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# SEED TRANSMISSION OF SOYBEAN BACTERIAL BLIGHT

JAMES B. KENDRICK AND MAX W. GARDNER[1]

WITH PLATE XVII

In 1919, Miss Coerper[2] described and illustrated the lesions of bacterial blight on soybean pods and stated that the seeds may become affected. Furthermore she found the disease on the first leaves of the plants in the field and suggested that the organism may live over winter on or within the seed. In a later report[3] on this disease from the University of Wisconsin, it is stated that the disease is seed-borne and that seed selection was being studied as one method of control.

In 1920, Wolf[4] in his description of the same or a very similar disease noted the lesions on cotyledons just emerging from the soil but did not find lesions on the pods. He expresses a belief, however, that the seed is primarily responsible for the overwintering and carriage of the disease and suggests that seed contamination occurs after the pods have matured. Wolf also observed that the disease appeared in new fields planted with seed from diseased fields.

Thus all the observational evidence has pointed towards seed transmission and it has proved comparatively easy to confirm this suspicion by greenhouse tests. In 1920 bacterial blight occurred in abundance in a field of soybeans near Lafayette and pod lesions were rather common. In October a considerable quantity of the ripening, infected pods (Pl. XVII,A) were collected. The seeds were removed and those borne directly under pod lesions were kept separate from the rest. Many of the seeds from under pod lesions showed actual lesions (Pl. XVII, B) as a result of the penetration of the infection through the ovary wall and others appeared to be smeared with the bacteria as noted by Miss Coerper.

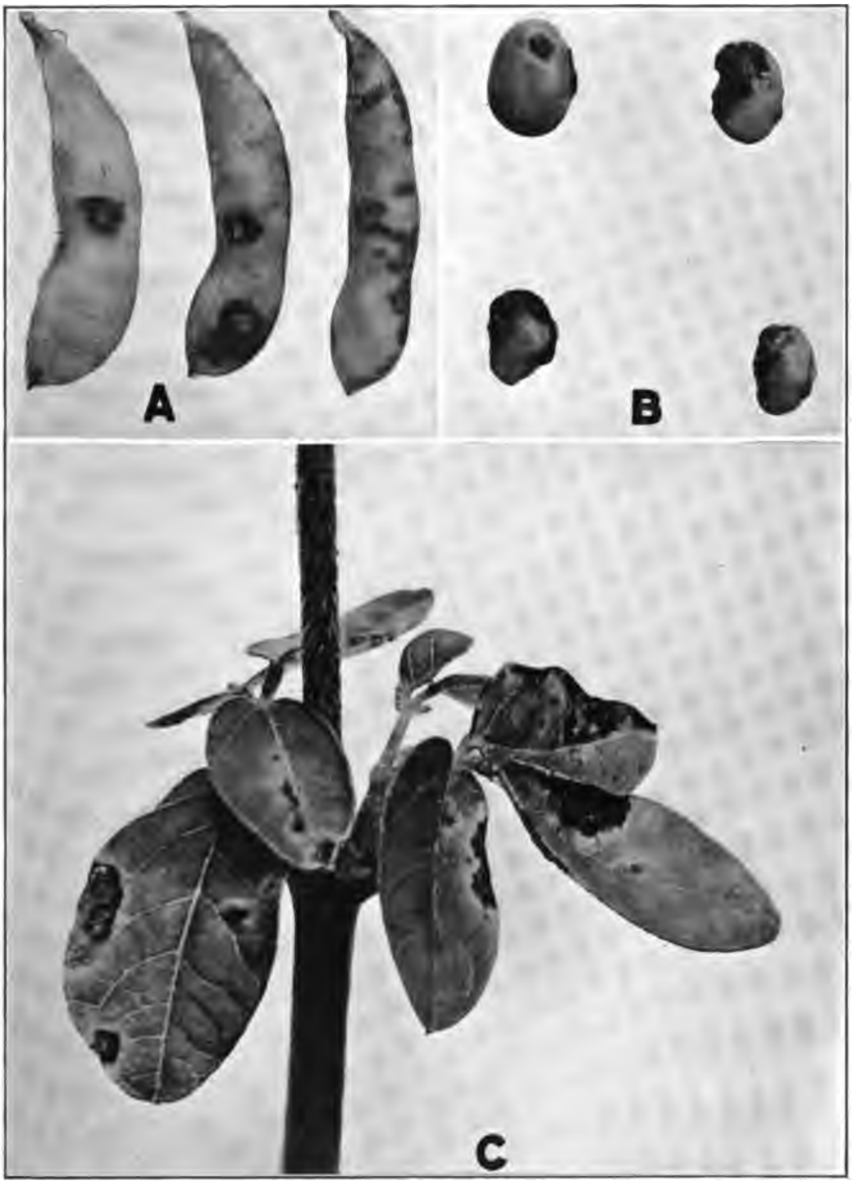
October 25, about 220 of these seeds from under pod lesions were planted in 40 small pots of sterilized soil and about 55 seeds which were borne in diseased pods but not directly under lesions were planted in

[1] Contribution from the Botanical Department of Purdue University Agricultural Experiment Station, Lafayette, Indiana.

[2] Coerper, Florence M. Bacterial blight of soybean. Jour. Agric. Research 18: 179–194. 1919.

[3] Annual report of the director (Experiments in farming). Plant pathology investigations. Wis. Agric. Exp. Sta. Bull. 319: 30–31. 1920.

[4] Wolf, Frederick A. Bacterial blight of soybean. Phytopath. 10: 119–132. 1920.




BACTERIAL BLIGHT OF SOYBEANS

Fig. A. Soybean pods showing bacterial blight lesions.

Fig. B. Seeds showing lesions (× 2).

Fig. C. Blight infection on leaves of secondary shoots from cotyledon node of seedling grown from seed from diseased pod. (Enlarged).

10 small pots of sterilized soil. The plants grew slowly and until January 25, 1921, no disease was noted. At that time 116 plants of the first series and 32 of the second series had come up and 13 of the 116 and three of the 32 showed lesions of bacterial blight on the leaves, especially the leaves on the secondary shoots from the cotyledon nodes (Pl. XVII, C). None of the 124 control plants grown in sterilized soil from seed selected from pods showing no lesions developed bacterial blight.

December 9, sixty seeds from underneath lesions were planted in 20 small pots of sterilized soil. Out of the 23 plants which had come up January 25, three showed blight lesions. Thirty seeds from diseased pods but not borne beneath lesions were planted the same date and, out of the 15 plants which were up January 25, one showed bacterial blight. None of the 106 control plants from seed from healthy pods developed the disease.

January 29, more of the seed from diseased pods but not from underneath lesions was planted in unsterilized soil and, out of 30 plants resulting, two showed the disease March 29.

A summary of the results of the tests in sterilized soil shows that 16 out of 139 plants from seed borne under pod lesions or about 11 per cent developed bacterial blight and that four out of 47 plants from seed not borne directly under pod lesions or about 8 per cent developed the disease. Thus it is evident that a considerable percentage of the viable seed from diseased pods gives rise to diseased seedlings. Also it would appear that infection may be carried externally or internally with the seed.

In order to determine the identity of the causal organism, isolations were made from a cotyledon node lesion and a leaf lesion. Typical whitish colonies appeared and successful inoculations and reisolations were obtained.

Owing to the confusion in the literature relative to this disease, it seemed necessary to determine whether the organism involved was *Bacterium glycineum* Coerper or *Bacterium sojae* Wolf by use of the tests conducted by Shunk and Wolf.[1] Three strains were used, one the original isolation from a nodal lesion tested for purity by poured plates and for pathogenicity by inoculations and designated as the Indiana strain, and the other two, strains No. 211 and No. 269 from the University of Wisconsin laboratory. The latter were two of the strains tested by Shunk and Wolf who concluded that No. 269 was typical of *Bact. glycineum* and No. 211 of *Bact. sojae*. These strains or species are to be distinguished by their pigment production and influence on the hydrogen-ion concentration of certain media.

[1] Shunk, I. V. and Wolf, F. A. Further studies on bacterial blight of soybean. Phytopathology **11**: 18–24. 1921.

Four series of tubed media containing 2 per cent peptone and as a carbon source either dextrose, saccharose, maltose, lactose or glycerin in concentrations of 1 per cent were prepared according to the method employed by Shunk and Wolf, that is, the carbon compounds were sterilized separately and added later. Three series were broth media. One contained the indicator brom cresol purple and another brom thymol blue in concentrations of about .0016 per cent. One contained no indicator. The fourth series consisted of agar slants containing the indicator brom cresol purple. All were adjusted to about pH = 7.3. Seven days after inoculation the pH values were determined by direct reading of the colors in the media containing the indicators and by the addition of the indicators mentioned as well as phenol red and methyl red to the series containing no indicator. The results are tabulated below.

| STRAIN | DEXTROSE | | SACCHAROSE | | MALTOSE | | LACTOSE | | GLYCERIN | |
|---|---|---|---|---|---|---|---|---|---|---|
| | pH | PIGMENT | pH | PIGMENT | pH | PIGMENT | pH | PIGMENT | pH | PIGMENT |
| Indiana ....... | 5.6* | None | 6.7 | None | 7.3 | None | 7.3 | None | 7.3 | None |
| (*Bact.*) 211 (*sojae*) ...... | 6.5 | None | 6.6 | None | 7.3 | None | 7.3 | None | 7.3 | None |
| (*Bact.*) 269 (*glycineum*). | 5.4 | None | 6.0[1] | Very light brown | 7.4 | Brown | 7.3 | Brown | 7.3 | Brown |

* After three weeks incubation these values became similar to those of No. 211.

The results with the Indiana strain checked very closely with other series of somewhat similar tests in which the other two strains were not used.

From these results it is evident that the Indiana strain is somewhat intermediate in its hydrogen-ion relations but more closely resembles No. 211 and in its failure to produce a brown pigment distinctly resembles No. 211. The pigmentation character in peptone media containing maltose or lactose seems to be the most reliable and convenient means of differentiating these strains.

In summary it may be said that bacterial blight of soybean is transmitted with the seed from diseased pods. The organism involved in these tests closely resembles the non-pigment-producing strain No. 211 of *Bact. glycineum* which is considered by Shunk and Wolf as identical with *Bact. sojae*.

## PHYTOPATHOLOGICAL NOTES

*Internal aecia of Puccinia albiperidia Arthur*.—In view of the general occurrence of internal rust sori as indicated by the observations of Clinton,[1] Colley,[2] Hungerford,[3] and others, the following report is of interest.

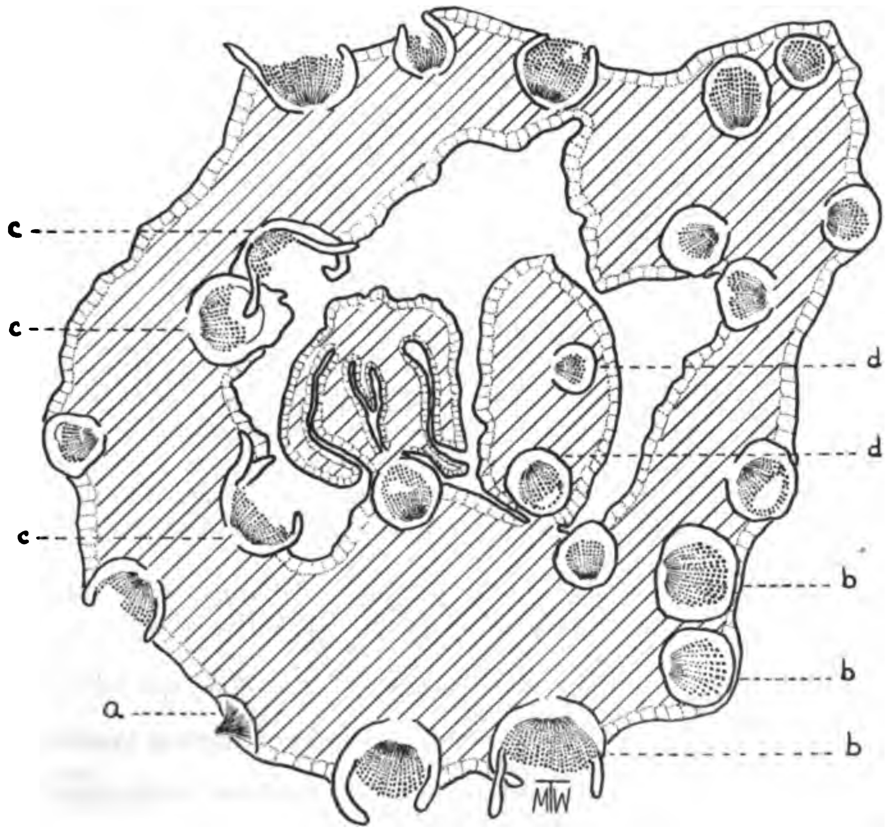



Fig. 1. Cross section through a fruit of Ribes glandulosum infected with Puccinia albiperidia Arth. showing pycnium (a), aecia (b), internal aecia (c) and aecia in seed (d).

Early in June, 1920, a rusted mummified fruit of *Ribes glandulosum* was collected at Temple, New Hampshire, by J. L. Richards in connection with work on *Cronartium ribicola*.The rust was determined as *Puccinia albiperidia* Arthur, the outer surface of the fruit being thickly

covered with aecia (Fig. 1, b) and with a very few pycnia (Fig. 1, a). A study of sections through the berry revealed the presence of abundant internal aecia (Fig. 1, c) projecting into the hollow central cavity. These internal aecia were perfectly normal in appearance and proportionately as numerous as those on the external surface. Aecia were also present in a few of the seeds. (Fig. 1, d.)

While internal aecia have been definitely observed in *Nigredo caladii* (Schw.) Arthur,[6] *Puccinia graminis* Pers.,[6] *P. graminis?*[3] *P. angustata* Peck,[6] *P. cari-bistortae*,[4] and *Gymnosporangium macropus* Lk.[1], so far as the writer can learn internal aecia have not been previously reported for *Puccinia albiperidia*.—MINNIE W. TAYLOR.

*Anaerobic bacteria in plant tissues.* Most bacteria described as causing plant diseases are aerobic, but some may grow in the absence of air if proper foods are available.[7] Instances are here recorded of anaerobic bacteria growing from pieces of diseased plant tissues inserted in culture media so as to be excluded from the air. No colonies of bacteria grew from similar pieces which were left on the surface of the media.

1. Sections of tumors on *Picea excelsa* produce bacterial colonies only when immersed more than 5 mm. in peptone-glucose agar or gelatinized arbutin.[8]

2. Sections of diseased roots of *Juglans regia* from Nuces, Aveyron, France[9] gave similar results. Grayish, gummous zoogloeae of bacteria grew from imbedded sections downward to the bottom of the culture tube. Those placed on the surface produced no colonies. These anaerobic bacteria may be responsible for the gummosis observed in the diseased roots, as they precede the fungus invaders and produce a black rôt.

From the above facts it appears that parallel cultures under aerobic and anaerobic conditions should be made.—JEAN DUFRENOY.

[1] Clinton, G. P. Notes on fungous diseases, etc. for 1908. Rept. Conn. Agric. Exp. Sta. **1907–1908**. 853. 1909.

[2] Colley, R. H. Discovery of internal telia produced by a species of Cronartium. Journ. Agric. Res. **8**: 329–332. 1917.

[3] Hungerford, C. W. Rust in seed wheat and its relation to seedling infection. Journ. Agric. Res. **19**: 257–276. 1920.

[4] Klebahn, H. Puccinia cari-bistortae. Zeitschr. Pflanzenkrank. **9**: 158. 1899.

[5] ———— Kryptogamenflora der Mark Brandenburg **Va.**: 101. 1912.

[6] Wolf, T. A. Internal aecia. Mycologia **5**: 303–304. 1913.

[7] Smith, E. F. A conspectus of bacterial diseases of plants. Annals Mo. Bot. Garden **2**: 377–401. 1915.

[8] Dufrenoy, Jean. Sur des tumeurs bactériemes expérimentales de l'Epicea. Comptes Rendus Acad. Sci. (Paris). 171: 874–876. 1920.

[9] ———— Bactéries anaérobies et gommose du Noyer. Comptes Rendus Soc. Biologie **84**: 132–133. 1921.

*Notes on Phoma insidiosa Tass. found on Sudan grass.* In September, 1920 leaves of Sudan grass infected with *Phoma insidiosa* were collected at Arlington Farm, Virginia. The Sudan grass was growing in an experimental plot together with different varieties of grain sorghum. The fungus had produced brownish-drab colored spots with indefinite outline, on various parts of the leaves. The pycnidia were scattered within the discolored areas. They were brown or black in color and had somewhat protrudent ostioles.

Cultures were started seven months after the leaves had been gathered. The conidia germinated, the mycelium grew, produced chlamydospores and pycnidia on cornmeal agar in the manner characteristic of *P. insidiosa,* except that when growing in the light the mycelium did not produce the pink stain in the medium as the cultures of *P. insidiosa* from sweet sorghum had done.[1] The fungus was found to be parasitic on the leaves of a variety of sweet sorghum called Early Amber. The seedlings, growing in covered glass dishes, were inoculated with a water suspension of conidia taken from the cornmeal agar cultures. In two weeks pycnidia were found on the leaves of two young plants out of the fifteen inoculated. The five check plants remained sterile. The conidia produced on these infected sweet sorghum leaves were plated in cornmeal agar. A growth characteristic of *P. insidiosa* followed but now the mycelium produced a pink discoloration of the cornmeal agar when growing in the light such as the sweet sorghum Phoma produced.

TABLE 1

*Measurements of pycnidia and conidia on leaves of Sudan grass and in cultures*

| SOURCE | PYCNIDIA | | | CONIDIA | | |
|---|---|---|---|---|---|---|
| | NO. MEASURED | RANGE IN μ | MEAN SIZE | NO. MEASURED | RANGE IN μ | MEAN SIZE |
| Leaf natural infection | 10 | 54 to 86 | 65 | 10 | 3.5 to 3.9 × 4.4 to 7.9 | 3.5 × 6.2 |
| Cornmeal agar cultures | 10 | 84 to 168 | 128 | 10 | 2.6 to 4.4 × 5.2 to 7.9 | 3.4 × 6.7 |
| Leaves of Early Amber seedlings inoculated in glass dishes | 10 | 63 to 198 | 115 | 10 | 2.6 to 3.5 × 5.3 to 7 | 3.2 × 6.2 |
| Cornmeal agar cultures | 10 | 45 to 108 | 75 | 10 | 2.6 to 3.5 × 5.3 to 7 | 3.4 × 6.5 |

CAROLINE RUMBOLD AND ELIZABETH K. TISDALE

[1] Koch, Elizabeth and Caroline Rumbold, Phoma on sweet sorghum. Phytopath. 11: 253 – 268. 1921.

*Wilting caused by walnut trees.* The writer's attention has been called from time to time to a number of cases of wilting of potato and tomato plants which was undoubtedly due to walnut (*Juglans nigra*) trees growing in the immediate vicinity. The plants show a pronounced wilting but do not lose their color or die as in the case of plants that have been attacked by wilt producing fungi or bacteria, or struck by lightning. The range of the wilting coincides very closely with the spread of the root system. The plants may wilt uniformly within a large circle or there may be areas of wilted and areas of erect plants which coincides with the distribution of the root system. In some cases the wilting was in a circular area around the trees in the field. In other cases in a semi-circular area next to trees along the margins of the fields. In all cases observed the plants beyond the spread of the roots of the trees were normal. A number of cases have been investigated by the writer and there is no doubt as to the cause of the wilting. So far as the writer has observed other crops are not affected by the walnut trees and other trees do not cause a wilting of crops or wild vegetation.—MEL. T. COOK.

*Russian Mycological and Phytopathological Society.*—Members of the American Phytopathological Society will be pleased to learn of the existence of a Russian sister society, now about a year old and apparently in good health. The writer of this note is in receipt of the constitution of the society and of a partial list of its members. He is indebted for these documents to an American, Mr. H. W. Truesdell, formerly engaged in phytopathological work in this country and now on a professional visit in Russia. While in Petrograd during the early part of March, 1921, he met there the well known Russian mycologist and plant pathologist, Prof. A. A. Jaczewski. He states that the latter gave him a great deal of information and copies and separates of a large number of his publications. Like the scientists in other lines of work, Professor Jaczewski has a number of unpublished manuscripts ready for the printer. Being shut off for a long time from the outside world, under the grave conditions of the war and civil war, Russia suffers from extreme shortage of typographic supplies and material. Professor Jaczewski also showed to his visitor his laboratory, which appeared to be "well equipped and in good order, as good as the best anywhere." However, on account of the fuel shortage it was unheated and "about 0° C." when the American visited it. Next the laboratory were two heated rooms, occupied by Prof. Jaczewski and his family. All the members of the family apparently were well and "living as well as anyone else at the present time" in Russia. As a crowning act of Russian hospitality, the Russian scientist invited his American guest to take tea with them.

Prof. Jaczewski is now the president of the Russian Mycological and Phytopathological Society. It was founded in 1920, and is affiliated with the Russian Botanical Society under the name of "Permanent Commission on Mycology and Phytopathology at the Russian Botanical Society." Other officers in Petrograd are: V. Tranzschel, vice-president; N. A. Naumov, secretary, and N. Vavilov, chief editor. The address is the same as that of the former Bureau of Mycology and Phytopathology before the war: 29 English prospect. There is also a branch of this Society in Moscow, of which Prof. V. Talyev is the president (address: Sadovaya Triumphalnaya, House of the Gubernskoe Zemstvo).

The constitution and the by-laws of the Russian Society reveal a somewhat broader field of activities than is usually associated with similar scientific societies in other countries. The society, in fact, appears to be organized for the purpose of *united* scientific endeavor and harmonized *work*. The object of the Society is three-fold: conduct of investigations in mycology and phytopathology, promotion of this work in Russia, and dissemination of mycological and phytopathological knowledge through the country. For the attainment of this object the following means are designated: meetings, conferences, and consultations; courses and public lectures; excursions and expeditions; organization of mycological stations, laboratories, museums, and like institutions; publications, and material assistance to the specialists carrying on the research. The Society is composed of actual, associate and honorary members. Foreign mycologists and phytopathologists may become actual as well as honorary members. The Society holds regular, annual, and extraordinary meetings. Joint meetings with economic entomologists are held from time to time as the necessity requires.

The partial list of members sent to the writer contains several familiar names which appeared previously in the pre-war Russian literature. Such are, for instance, in addition to the above mentioned officers of the Society: Bondartsev, Dorogin, Ohl, Lebedeva. Most of the members are new workers, a great proportion of whom are women. Of the thirty-seven members named in this list, twenty-two are men and fifteen women. This entry into the field of plant pathology of a relatively large number of Russian educated women is a new and interesting social phenomenon.—M. SHAPOVALOV.

*Ravn Scandinavian-American fellowship in plant pathology.*—In recognition of the important services to humanity, particularly in the field of plant pathology, of the late Dr. F. Kölpin Ravn of Denmark, a movement was started in connection with the Chicago meetings of the American Phytopathological Society looking toward the establishment of a fellowship in the United States for graduate students of Norway, Sweden, or Denmark, who are planning to make plant pathology their life work. The matter was referred to a special committee of which Dr. L. R. Jones was made general chairman. Others on the committee are Drs. Donald Reddick, A. G. Johnson, H. H. Whetzel and Mr. R. Kent Beattie.

The committee in considering ways and means for handling the whole matter will welcome suggestions from any source bearing on any phase of the proposition.

*Personals.*—Dr. Arthur H. Graves, of New Haven, Conn., has been appointed curator of public instruction at the Brooklyn Botanic Garden to take effect September first. Dr. Graves was formerly assistant professor of botany in the Sheffield Scientific School and the School of Forestry of Yale University, and more recently professor of botany at the Connecticut Women's College.

Prof. Dr. C. Ferdinandsen, professor of plant pathology at the Royal Agricultural College, Copenhagen, is making a brief visit to this country. He visited Washington, D. C., Madison, Wis., Ithaca, N. Y., and New York City. While in Washington he addressed the Phytopathological Seminary on Phytopathology in Denmark. Dr. Ferdinandsen is the successor to Dr. F. Kölpin Ravn who was so well known to American pathologists.

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VOLUME 11

# Phytopathology

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CONTENTS

# PHYTOPATHOLOGY

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SEPTEMBER, 1921

## MOSAIC DISEASE OF SUGAR BEETS

W. W. ROBBINS

WITH EIGHT FIGURES IN THE TEXT

### INTRODUCTION

The following account of mosaic of sugar beet is based upon field observations and experimentation in northern Colorado and western Nebraska. It has been thought well to place the data and conclusions obtained to date in published form, in view of the rather exceptional interest among plant pathologists at this time in the mosaic diseases.

Scattered cases of sugar beet mosaic were observed in beet fields of the irrigated sections of northern Colorado in 1917, more in 1918 and 1919, and an increasing number in 1920. At present it appears to be confined chiefly to seed beets and stecklings[1] and to fields of commercial beets adjacent to diseased seed beets or stecklings. Field observations in northern Colorado, eastern Colorado and western Nebraska in 1920 showed no cases of transmissible mosaic on commercial beets which were more than one to one and one-half miles from possible sources of infection.

It is the practice in the beet seed growing sections to raise stecklings and seed bearing plants on the same farm. The obvious reason for this is to save labor in the spring in the hauling of roots from the silo to the point where they are to be set out. Consequently, steckling plants and seed-bearing plants are frequently in close proximity. This undoubtedly accounts for the greater prevalence of mosaic on stecklings than on commercial beets, except those near diseased seed beets, for diseased seed-bearing plants are the chief sources of infection.

[1] Beets held over winter for the production of seed the following season are called "stecklings." The seed from which stecklings are grown is planted at the same time and in the same manner as commercial beet seed. Commercial beets are thinned by hand, leaving one beet every 10 to 14 inches. Stecklings, however, are not thinned at all, or only by harrowing crosswise the rows, thus leaving three to five beets, or more, per foot. Prior to digging in the fall, the tops are mowed off; the stecklings are then siloed in earth trenches.

As far as the writer can determine, mosaic of sugar beets has not attracted attention in any other of the sugar beet growing sections of this country or of Europe. Lind (4) reports mosaic on garden beets in Denmark, and a few other places, chiefly southern Sweden, the north of France, and Berlin, but specifically mentions that the disease is never found on sugar beets.

The mosaic of sugar beet described herein is distinct from curly-top of sugar beet, a disease so prevalent in Utah and California.

The economic importance of curly-top has stimulated extended investigation. The most important facts relating to curly-top may be found in publications by Linhart (5), Townsend (9), Ball (2), Shaw (7), Bunzel (3), and Smith and Boncquet (8).

In northern Colorado and western Nebraska, where mosaic of sugar beet is most prevalent, true curly-top rarely occurs. One may find in an entire season's field work only a few isolated cases of diseased beets which even suggest curly-top.

The only symptoms of mosaic and curly-top in common are curling and crinkling of the leaves. The inward and retracted type of leaf curl in curly-top is seldom if ever found in mosaic-affected beets. The vein distortion of curly-top is far more pronounced than, and quite different in character from, that in mosaic. Vein distortion does not occur in primary-infected mosaic leaves. Moreover, in no cases does vein distortion appear as knot-like swellings, so typical on leaves of curly-top. Nipple-like protuberances, so characteristic of curly-top leaves, are never associated with mosaic. In mosaic plants there is no shortening and bowing inward of the petioles as in the leaves of plants with curly-top. The crown of mosaic plants remains normal, and the roots never throw out dense masses of rootlets; furthermore, there is no apparent stunting of first-year beets, and seldom of second-year beets. The brittleness of mosaic leaves is confined to secondarily infected plants, and has not been observed on plants with primary infection. This is unlike curly-top. The outstanding symptom of beet mosaic is a pronounced mottling of the leaves, which symptom is not evident in curly-top.

There is another sugar beet disease scattered throughout commercial fields of the territory studied which has some mosaic characters, but which the writer believes to be distinct from true transmissible mosaic. The plants are distinguished by their asymmetry. One-half of the plant, including both top and root, is dwarfed; the other half is apparently normal. The affected leaves are small, thick, curled, twisted and the mesophyll tissue bordering the veins of the leaf is pallid. The root shows eccentric growth, and seldom attains normal size. All attempts to transmit this disease by means of aphids have met with failure.

Under similar conditions, however, true mosaic is readily transmitted by aphids. Moreover, in the scope of our observations, diseased plants of the asymmetrical type are not centers of infection in the field, whereas plants with true mosaic are centers of infection.

No definite data can yet be presented as to the effect of mosaic on quality and quantity of seed produced, or upon the yield and quality of roots. However, here and there in seed beet fields are plants so badly diseased, with leaves so heavily mottled, crumpled, twisted and contorted, that the yield of seed is reduced to a very small amount.

## SYMPTOMS

### *Mottling*

Mottling of the leaves is the characteristic symptom of sugar beet mosaic. This mottling is produced by the occurrence of light green areas on the foliage. There is much variation in the degree of paleness in the lighter green patches; in some instances these are barely discernible by reflected light, whereas if the leaf is observed by transmitted light the spots or areas are plainly visible. Frequently, the paler areas are very sharply delimited from the bordering normal green of the mesophyll; and usually in such instances the paler portion takes the form of a ring surrounding darker tissue.

The light green areas also vary widely in shape. The leaf may appear finely speckled, the areas being very minute dots. This condition was observed chiefly on first-year beets grown in the greenhouse. Or, the areas may be elongate, circular, angular or irregular.

Any part of the leaf may be involved. A young leaf unfolding may be mottled throughout from base to tip; the pallid areas in such are usually very irregular, appearing as light green blotches. Again, a leaf may be mottled only at the base, the portion involved varying considerably in size. In a day or two, the mottling may spread from base to tip. Frequently, only one-half of a leaf shows mottling. The normal half may remain so throughout the season, or later become affected in a manner similar to its adjoining half. Seldom does one observe a leaf mottled only at the tip.

In the youngest leaves, the pallid, affected tissue may predominate, whereas in older leaves the normal dark green tissue usually predominates. Infected plants are seldom lighter in color than healthy individuals, and it is rarely possible to identify a diseased plant from a distance.

If one examines a plant in mid-season, the mosaic is most conspicuous on the young heart leaves. The pattern may be entirely masked or very much diffused on the older leaves. However, a mature plant may manifest mosaic symptoms on every leaf. This condition has been observed in both first-year and second-year beets.

There are instances of seed beets with distinct mottling extending upward to include not only the floral bracts but the perianth segments. However, no distortion of stamens and pistils has been observed.

*Malformation*

Malformation may or may not be associated with mottling. As a rule, however, a young leaf with marked mottling shows puckering and crinkling of the mesophyll tissue.

A very characteristic malformation, chiefly on seed beets grown under greenhouse conditions, is a bending back of the leaf near the tip. About

FIG. 1. LEAF MALFORMATIONS ASSOCIATED WITH MOSAIC OF SUGAR BEET
The curling at the tip is preceded by necrosis in the midrib back of the leaf tip.

one-third of the way back from the leaf tip, marginal growth apparently ceases earliest, as the most pronounced curling is at this point on both margins. The main vein from which lateral veins arise, leading to these marginal points, becomes affected first. This affection is first

manifest by a crinkling and apparent shortening of the vein, as though the vascular strands were being contracted lengthwise. Later, the vein so affected becomes unevenly discolored, and later totally darkened and shrivelled. (Figs. 1 and 2.) The cessation of growth at the margins

FIG. 2. LEAF MALFORMATIONS ASSOCIATED WITH MOSAIC OF SUGAR BEET
More advanced stages than those shown in Figure 1.

is preceded and caused by some disturbance in the functioning of the vascular tissue which is tributary to any particular marginal zone.

This folding back of the leaf tip, sometimes to form a pocket, the curling and crinkling of the leaf margin and tip, and frequently death of the tip later, are very striking and constant symptoms associated with mottling and greenhouse-grown seed beets. The same symptoms have been observed on seed beets in the field, but the proportion showing them is far less than that of plants in the greenhouse. The crinkling and puckering in extreme cases may take the form of conspicuous, bladdery areas over the leaf surface.

The first leaves produced from a mother beet carrying mosaic, are usually yellowish green, mottled, much curled, crumpled and crinkled and abnormally thick and brittle. This crinkling and puckering often occur in young leaves from a normal mother beet, but in a leaf showing

both malformation and mottling, a degree of crinkling and puckering approaching abnormality is attained. Leaves affected as above may partially outgrow these symptoms, and become quite normal as far as can be ascertained by the eye. In most instances, however, they do not recover, but remain mottled, thick, brittle and more or less malformed. They may or may not increase in size. (Fig. 3.)

FIG. 3. MOSAIC OF SUGAR BEETS
Heavily mottled and malformed leaves and floral bracts.

The environmental conditions under which the plants grow appear to be associated with the expression of mosaic. The mottled phase without malformations is predominant under field conditions, both as concerns first-year and second-year growth. Seed plants in the greenhouse usually develop marked malformations in leaf growth.

## PATHOLOGICAL ANATOMY OF DISEASED PARTS

In a cross-section of the mid-rib in that portion of the leaf of a seed plant showing curling and very marked distortions, the vascular area

and tissue adjoining show characteristic symptoms. (Fig. 4.) There is a darkening of the vascular tissue and cells adjacent thereto; many of the phloem elements are filled with a yellowish or reddish brown substance; the walls of the phloem cells are darker in color and thicker than normal; wood fibers are for the most part not involved; however, in advanced stages, these may have a deposit in them of the same brown material found in other cells of the vascular region. In the parenchyma cells bordering the vascular strands, there may be deposits of the substance mentioned above; and also in the intercellular spaces such deposits are occasionally found. This pathological condition resembles that of phloem-necrosis observed in potato plants, as described by Quanjer, (6) and Artschwager, (1).

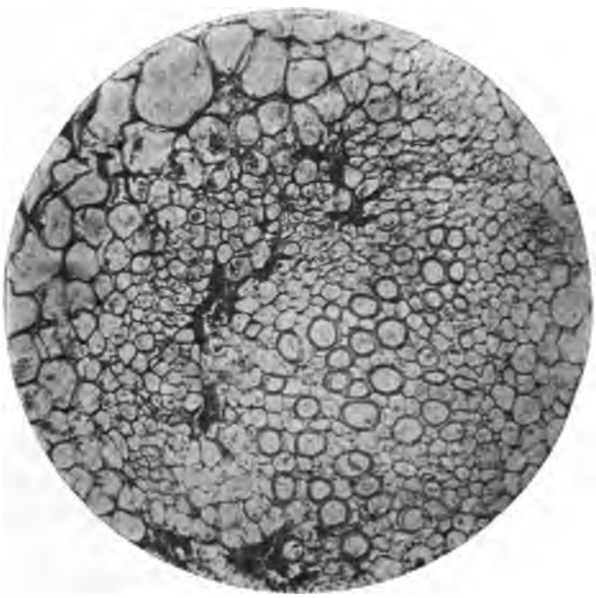

FIG. 4. NECROTIC PHLOEM IN VASCULAR BUNDLES OF MIDRIB OF LEAF SHOWING MALFORMATIONS ILLUSTRATED IN FIGURES 1 AND 2.

As would be expected, in leaves which have necrotic phloem tissue in the veins the transportation of carbohydrates, manufactured beyond the diseased portion, is hindered. This is evidenced by abnormal starch accumulations. The normal, fresh, green beet leaf contains no starch, except late in the afternoon of a bright, sunny day, at which time very small granules may be detected in the plastids. Primarily infected beet leaves are similar to normal ones as to the starch accumulation within them. On the other hand, thick brittle, heavily mottled leaves of secondary diseased plants (seed beets) usually show an abundance of starch within them, when tested at any time during the day, although

more in the afternoon than in the forenoon. That portion of a leaf beyond the parts of the veins which have necrotic phloem, shows an extraordinary accumulation of starch.

### DEVELOPMENT OF DISEASE

The appearance of external symptoms comes on very abruptly as a rule. Individuals apparently free from mosaic one day, will manifest unmistakable symptoms the following day. Usually the first mottling shows up on the heart leaves, and in 5 to 7 days, the mottling has spread, generally, to include its maximum area.

The mosaic pattern may disappear entirely or later be demonstrated with difficulty in first-year, as well as in second-year sugar beets.

Cases of apparent recovery from sugar beet mosaic have been observed. In three plots of seed beets containing a total of 684 individuals, 26.7 per cent of all those which showed mosaic at the beginning of the season or at some date throughout the season were apparently free from the disease at harvest date. The emphasis here needs be placed upon "apparently", for it is altogether likely that such individuals are still sources of infection.

The fact that a plant has outgrown its symptoms is no evidence that it has recovered from the disease. This view is further strengthened by experiments with stecklings. Beets which were apparently free from mosaic when taken in September from plots containing diseased individuals were topped, and set out in the greenhouse. The first leaves which developed showed characteristic mosaic symptoms.

### PERIOD OF INCUBATION

The cage experiments described below establish an incubation period on seed beets under greenhouse conditions of approximately 24 days; and on young seedling plants bearing eight to ten leaves growing under similar conditions, of 12 to 18 days.

There was in 1920 a gradual increase in the amount of mosaic in the experimental plots through the season, as figure 8 graphically shows, but the most rapid increase came after August 21. It is possible that this phenomenon is related to the appearance and migration of insect broods.

### TRANSMISSION OF THE DISEASE

#### *Field Studies*

There is abundant evidence that the mosaic of sugar beet is carried from diseased to healthy individuals.

A tract of land south of Longmont, Colorado, was planted April 7–9, 1920, to mother beets grown on the experimental farm of the Great Western Sugar Company in 1919. There were 11,122 individual seed plants on this tract. On May 10, approximately 55 per cent of all

plants had unmistakable mosaic symptoms. On this date, the roots had produced a cluster of small leaves. By July 6, 99.3 per cent of all plants showed the mosaic disease. (Fig. 5.)

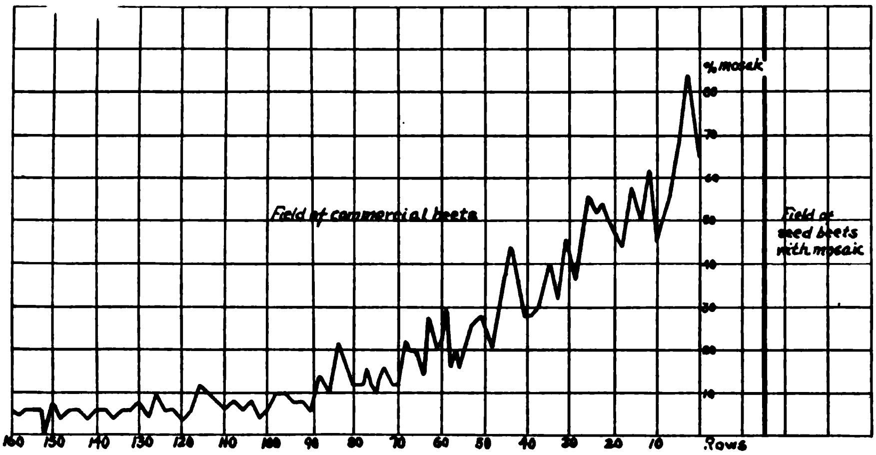


FIG. 5. SPREAD OF SUGAR BEET MOSAIC IN THE FIELD

The field directly north of the tract growing the diseased seed beets, was planted to commercial beets on April 15. On July 24, the percentage of mosaic in this field was determined. In doing this the percentage of mosaic was obtained for each row up to number 84, and from there on for every other row up to row number 180. Row 1 (Fig. 5) is nearest the field of diseased seed beets, and row 160, farthest from it. If insects carry mosaic from affected seed beets to commercial beets, it is altogether probable that the rows closest to the diseased beets would have the largest percentage of individuals with mosaic, and that there would be a decrease in the percentage across the field. That this is the case may be seen from figure 5.

On the experimental farm of the Great Western Sugar Co., Longmont, Colorado, there are, in one of its rotation experiments, 21 plots of approximately one-twentieth acre each. In each series there are 7 plots, which are in triplicate. The cropping on these plots is shown in figure 6.

It will be noted that three of the plots, 3, 3′ and 3″, were planted to mother beets in 1920. The mothers were set out from March 31 to April 6. On May 17, 95.7 per cent of the plants on plot 3, 93.5 per cent of those on plot 3′, and 97.9 per cent of those on plot 3″ showed distinct mottling. At this time, the leaves were very small, and in a dense cluster on the crown. Plots 1, 4, 5 and 7 of each series were seeded to commercial beets on May 17. The young plants were emerging on May 25.

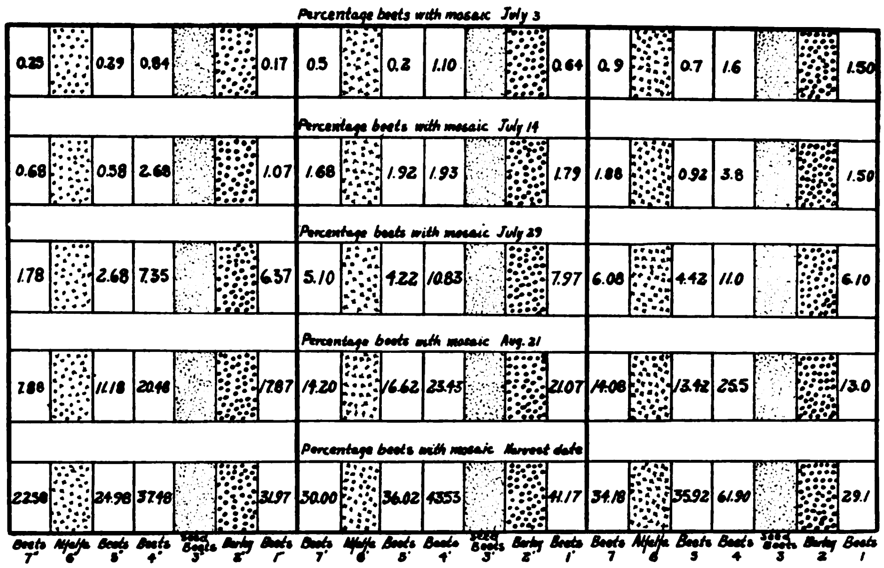


FIG. 6. SPREAD OF SUGAR BEET MOSAIC ON ROTATION PLOTS.
Plots 3, 3′ and 3″ containing diseased seed beets are sources of infection. Note that the plots of commercial beets nearest to affected seed beets have the largest percentage of diseased individuals: also note increase in any one plot as the season advances.

These plots were examined frequently to detect the first evidence of mosaic. It was suspected that the disease would be carried from the adjacent affected seed beet plots. The first cases of mosaic on the seedling plots were on July 3, as follows:

TABLE 1

*Mosaic on sugar beet seedlings, July 3*

| PLOT | MOSAIC NO. PLANTS | MOSAIC PERCENTAGE OF PLANTS |
|---|---|---|
| 1 | 31 | 1.5 |
| 4 | 36 | 1.6 |
| 5 | 12 | 0.7 |
| 7 | 21 | 0.9 |
| 1′ | 10 | 0.64 |
| 4′ | 20 | 1.10 |
| 5′ | 4 | 0.20 |
| 7′ | 9 | 0.50 |
| 1″ | 3 | 0.17 |
| 4″ | 16 | 0.84 |
| 5″ | 5 | 0.29 |
| 7″ | 4 | 0.25 |

TABLE 2

*Summary of each plot of commercial beets:*

*Rotation 1, showing total numbers of beets with mosaic on certain dates*

| PLOT | JULY 3 NEW: | TOTAL | JULY 10 NEW: | TOTAL | JULY 14 NEW: | TOTAL | JULY 22 NEW: | TOTAL | JULY 29 NEW: | TOTAL | AUG. 6 NEW: | TOTAL | AUG. 21 NEW: | TOTAL | AUG. 28 NEW: | TOTAL | SEPT. 13–24 NEW: | TOTAL | WITHOUT MOSAIC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 31 | 31 | 0 | 31 | 0 | 31 | 47 | 78 | 44 | 122 | 46 | 168 | 90 | 258 | 133 | 391 | 182 | 573 | 1384 |
| 4 | 36 | 36 | 24 | 60 | 24 | 84 | 86 | 170 | 69 | 239 | 107 | 346 | 205 | 551 | 524 | 1075 | 261 | 1336 | 812 |
| 5 | 12 | 12 | 3 | 15 | 1 | 16 | 35 | 51 | 26 | 77 | 50 | 127 | 106 | 233 | 172 | 405 | 216 | 621 | 1098 |
| 7 | 21 | 21 | 8 | 29 | 13 | 42 | 50 | 92 | 40 | 132 | 57 | 189 | 114 | 303 | 232 | 535 | 196 | 731 | 1390 |
| 1′ | 10 | 10 | 8 | 18 | 10 | 28 | 52 | 80 | 43 | 123 | 61 | 184 | 144 | 328 | | | 315 | 643 | 920 |
| 4′ | 20 | 20 | 10 | 30 | 25 | 55 | 78 | 133 | 91 | 224 | 77 | 301 | 161 | 462 | | | 379 | 841 | 1042 |
| 5′ | 4 | 4 | 7 | 11 | 21 | 32 | 22 | 54 | 33 | 87 | 62 | 149 | 140 | 289 | | | 316 | 505 | 1118 |
| 7′ | 9 | 9 | 4 | 13 | 17 | 30 | 34 | 64 | 28 | 92 | 31 | 123 | 132 | 255 | | | 281 | 536 | 1235 |
| 1″ | 3 | 3 | 0 | 3 | 16 | 19 | 66 | 85 | 26 | 111 | 52 | 163 | 144 | 307 | | | 230 | 537 | 1157 |
| 4″ | 16 | 16 | 6 | 22 | 28 | 50 | 53 | 103 | 37 | 140 | 42 | 182 | 208 | 390 | | | 324 | 714 | 1184 |
| 5″ | 5 | 5 | 4 | 9 | 1 | 10 | 16 | 26 | 21 | 47 | 30 | 77 | 117 | 194 | | | 239 | 433 | 1287 |
| 7″ | 4 | 4 | 0 | 4 | 7 | 11 | 8 | 19 | 10 | 29 | 21 | 50 | 77 | 127 | | | 235 | 462 | 1137 |

Note—On account of irrigation and rain it was impossible to make observations on Plots 1′ to 7′, on August 28.

It will be noted from the above that the largest percentage of diseased plants occurs on plots 4, 4′ and 4″ which are adjacent to the affected seed beets, plots 3, 3′ and 3″. At all times throughout the season, and at harvest time, the plots closest to the diseased seed beets showed the highest percentage of mosaic.

This fact is shown in tables 2 and 3, and in figures 6 and 7.

If we follow the progress of mosaic by rows in plots 4, 4′ and 4″, which border the diseased seed beet plots, we again see that mosaic spreads from the diseased plants as a center. This fact is brought out in the table 3 and figures 6 and 7. In plots 4, 4′ and 4″, row 1 in each case is nearest the affected seed beets, of plots 3, 3′ and 3″.

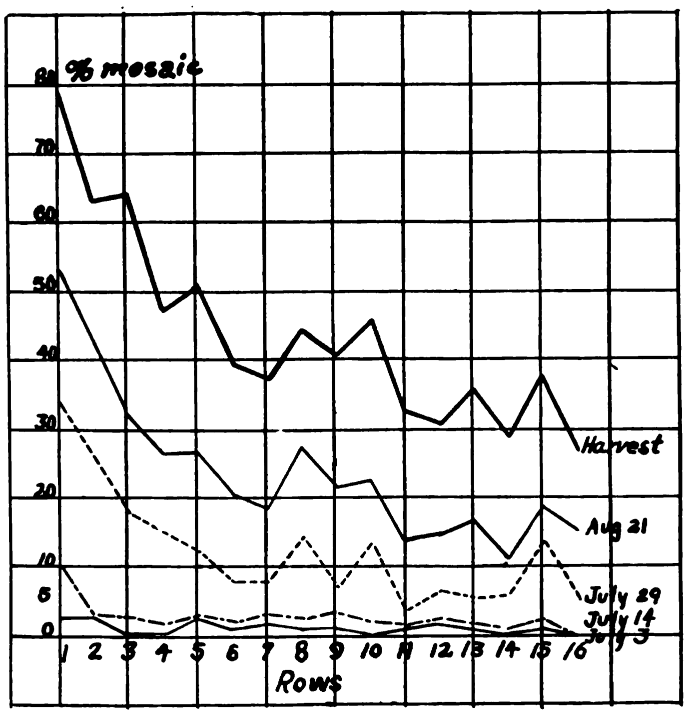


FIG. 7. PERCENTAGE OF MOSAIC BY ROWS ON FIVE SUCCESSIVE DATES

*Insect Cage Experiments*

The type of insect cage used in this study has a wire frame-work covered with sheeting muslin, into which are sewn two celluloid windows, 6 × 14 inches. The cages proved effective in preventing the movement of aphids in or out, and enough light is admitted to permit normal plant growth.

TABLE 3

*Percentage of mosaic in plots 4, 4′ and 4″ in each row on five successive dates*
*(These plots are adjacent to plots having seed beets)*

| | Row | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plot 4 | July 3 | 3.8 | 1.6 | 0.9 | 0.8 | 2.5 | 1.5 | 0.0 | 3.4 | 3.7 | 0.8 | 1.6 | 1.9 | 0.9 | 1.5 | 1.8 | 2.6 |
| | July 14 | 3.8 | 1.6 | 3.6 | 1.6 | 4.1 | 3.8 | 3.2 | 3.4 | 5.1 | 4.8 | 3.3 | 1.9 | 4.9 | 1.5 | 7.1 | 15.5 |
| | July 29 | 10.7 | 5.6 | 6.3 | 7.2 | 7.4 | 6.0 | 5.6 | 8.4 | 16.3 | 6.2 | 13.2 | 13.0 | 12.1 | 18.8 | 20.3 | 36.2 |
| | Aug. 21 | 18.3 | 15.2 | 18.9 | 15.2 | 16.0 | 17.2 | 15.3 | 21.8 | 28.1 | 22.4 | 29.6 | 30.4 | 37.8 | 45.0 | 50.4 | 73.3 |
| | Harvest | 52.6 | 30.8 | 46.3 | 39.8 | 46.3 | 43.5 | 43.5 | 48.7 | 67.4 | 59.4 | 63.6 | 64.8 | 71.7 | 84.2 | 80.5 | 92.2 |
| Plot 4′ | July 3 | 0.8 | 0.0 | 0.0 | 0.8 | 0.0 | 0.78 | 0.98 | 0.0 | 0.0 | 0.9 | 2.4 | 1.5 | 0.9 | 2.4 | 0.8 | 0.8 |
| | July 14 | 2.4 | 0.9 | 0.0 | 1.6 | 0.0 | 1.56 | 0.98 | 0.0 | 0.0 | 3.6 | 2.4 | 2.3 | 5.4 | 8.8 | 2.4 | 8.8 |
| | July 29 | 4.0 | 1.6 | 2.5 | 5.6 | 7.2 | 3.9 | 3.9 | 4.5 | 5.4 | 6.3 | 9.6 | 5.5 | 12.6 | 16.4 | 8.8 | 19.2 |
| | Aug. 21 | 12.0 | 9.0 | 9.1 | 14.4 | 10.0 | 12.5 | 14.7 | 12.7 | 16.2 | 27.0 | 20.8 | 19.5 | 31.5 | 31.8 | 42.4 | 45.6 |
| | Harvest | 21.4 | 23.8 | 15.3 | 25.4 | 21.8 | 35.3 | 26.2 | 34.5 | 33.6 | 46.2 | 37.6 | 41.4 | 40.0 | 57.4 | 60.6 | 79.8 |
| Plot 4″ | July 3 | 0.0 | 0.8 | 0.0 | 0.9 | 1.7 | 0.8 | 0.0 | 0.9 | 0.9 | 1.6 | 0.8 | 2.5 | 0.0 | 0.0 | 2.4 | 2.9 |
| | July 14 | 0.0 | 2.4 | 1.0 | 1.8 | 2.6 | 1.5 | 1.7 | 3.8 | 2.8 | 3.3 | 2.3 | 3.3 | 1.9 | 2.9 | 2.2 | 10.3 |
| | July 29 | 4.8 | 13.2 | 6.0 | 5.8 | 7.0 | 3.3 | 13.9 | 6.7 | 14.1 | 8.1 | 8.4 | 12.4 | 15.0 | 17.6 | 26.6 | 34.0 |
| | Aug. 21 | 15.2 | 19.0 | 11.0 | 16.5 | 14.8 | 13.4 | 22.6 | 21.9 | 27.3 | 18.7 | 20.6 | 26.4 | 26.4 | 31.6 | 43.5 | 53.3 |
| | Harvest | 26.4 | 38.0 | 29.0 | 35.9 | 30.4 | 32.8 | 46.0 | 40.9 | 44.3 | 37.4 | 39.7 | 50.4 | 46.2 | 63.9 | 63.7 | 79.2 |

The common greenhouse aphid (*Myzus persicae*) was used. The initial brood was secured from carnations in a commercial greenhouse. The aphids were allowed to multiply on carnations in an insect cage.

Previously, roots were set in the greenhouse bed and caged. These included:

1. Beets which showed distinct mosaic symptoms at time of harvest.
2. Beets from commercial field and free from all symptoms.
3. Beets which showed no mosaic symptoms at time of harvest, but which grew in plots containing diseased individuals.

Beets in groups 1 and 3 soon developed mosaic symptoms in the greenhouses whereas those in group 2 remained normal. Aphids from the caged carnations were introduced on to one plant of each group, and after being allowed to feed and multiply for a period, were caged with healthy seed beets and healthy seedlings. Limited space in the greenhouse necessitated the use of a small number of cages.

Aphids which fed on the seed beet (group 1) with mosaic were transferred to three healthy seed beets on December 14. On January 6, all had distinct mottling.

Aphids which fed on the seed beet free from mottling (group 2) wer

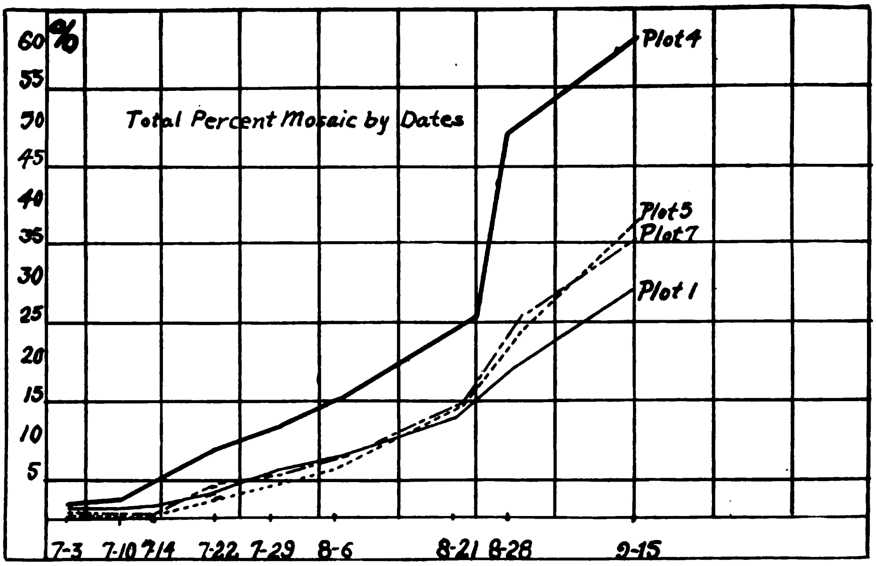


FIG. 8. PROGRESS OF MOSAIC IN FOUR ROTATION PLOTS AS THE SEASON ADVANCED

transferred to one healthy seed beet on December 14. The aphids fed and multiplied rapidly. No mosaic symptoms developed.

Aphids which fed on the mosaic seed beet of group 3 were transferred to a healthy seed beet on December 14. On January 6, unmistakable mosaic symptoms were in evidence.

Aphids which fed on the seed beet (group 1) with mosaic were transferred to two caged pots containing 7 seedling plants on January 4. On January 22, 6 plants had developed mosaic.

Aphids which fed on the seed beet (group 2) free from mottling were transferred to two caged pots containing 10 plants on January 4. All plants remained normal.

Aphids which fed on the seed beet (group 3) with mosaic, were transferred to two caged plots containing 11 plants on January 4. On January 22, 8 plants had developed mosaic.

Experiments on insect transmission were repeated; aphids from diseased and healthy plants were transferred to seedling beets March 7. The check plants remained normal. Those to which aphids from diseased beets were transferred had distinct mottling on March 21. This gives an incubation period of 14 days which is considerably shorter than that obtained in the previous test. This is probably due to the temperature in the greenhouse which was somewhat higher for the latter period. A third series of insect inoculations was started on March 17. Mottling was in evidence March 29. This gives an incubation period of 12 days.

At the present, other insects which frequent the sugar beet are being tested as possible conveyors of mosaic.

### *Artificial Inoculations*

Up to date, all attempts to transfer the disease by means of needle inoculations, by the injection of freshly prepared juice with a hypodermic needle, and by the insertion of freshly crushed fragments of mosaic leaves into slits on the leaf petioles and crown, have been unsuccessful.

### *Seed Transmission*

Up to this time, there is no evidence of seed transmission of sugar beet mosaic. Lind (4) states that the mosaic disease of garden beets is not conveyed by the seed.

In 1920, seed was collected from a plant growing on a tract west of Denver, Colorado, the leaves of which were extremely heavily mottled, crinkled, thick and brittle. The mottling extended upward to include not only the floral bracts, but the perianth segments as well.

This seed was threshed by hand, and a hundred or more of the seed were planted in pots in the greenhouse. The pots were caged. All seedlings were normal, showing no evidence of mosaic. It was anticipated that although there might be no embryo-transmission, the disease would be conveyed by the adhering perianth but such does not seem to be the case.

## WINTERING-OVER OF MOSAIC

A steckling may carry the infectious principle or virus. Roots from plants which had mosaic were topped and placed in a cool cellar to undergo a period of rest. When such roots were set out in the greenhouse the very first leaves to unfold were characteristically mottled and often malformed.

As has been pointed out, plants apparently disease-free at harvest time and which had been so throughout the season may be carriers, as is evidenced by the early development of symptoms on the roots when set out.

A high percentage of the seed beets on the experimental farm of the Great Western Sugar Company in 1920, which came from diseased steckling fields of 1919, were clearly and unmistakably diseased, as was indicated by the mottling and puckering of the first leaves within a few days after these unfolded. In fact, mottling could often be detected on a leaf not yet fully unrolled by spreading it open.

If the disease is seed transmitted, this is very rarely the case.

There remains the possibility of wintering-over on such weeds as *Chenopodium album* and Amaranthus spp., and in the soil, neither of which possibilities have been investigated thus far.

## CONTROL

It has been demonstrated experimentally that the infectious material may be carried by aphids from a diseased to a healthy plant. There is no evidence as yet that there is embryonic transmission of the infective principle. Up to this time the disease is found chiefly in breeding plots, seed fields and steckling fields. Clearly, stecklings are inoculated by insects flying from near-by diseased seed beets. The virus retains its vitality in the steckling throughout the silo period, and the resulting seed plant develops the disease. These affected seed plants are in turn centers of infection. Of course, a diseased commercial beet also may be a center of infection.

To have disease-free seed plants we must have disease-free stecklings. This means that steckling fields should be such a distance from seed fields that there will be little chance of insects conveying the inoculum. The past season we have observed transmissible mosaic on commercial beets and stecklings to a maximum distance of 1½ miles from diseased seed beets. However, the diseased plants at that distance were very few in number.

## SUMMARY

1. Mosaic of sugar beet has become increasingly prevalent the last few years in steckling and seed beet fields of northern Colorado and

western Nebraska. It also occurs in commercial beet fields near a possible source of infection.

2. Mosaic of sugar beet is distinct from curly-top of sugar beet.

3. The principal symptom is mottling of the leaves, which may or may not be associated with their malformation.

4. Aphids carry the infectious principle.

5. Under greenhouse conditions, an incubation period on seed beets of approximately 24 days has been established; on seedling plants from 12 to 18 days.

6. Thus far, evidence of seed transmission is lacking.

7. The virus retains its vitality in the steckling throughout the silo period. This is the only means of wintering-over thus far known.

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# BITTER PIT IN APPLES AND PEARS: THE LATEST RESULTS IN PREVENTIVE MEASURES

D. McAlpine

After five years' continuous experimental investigation into the cause of bitter pit, and having regard to any remedial measures suggested thereby, I believe that it would facilitate further research to state as briefly as possible what has been done and what remains to be done. Five voluminous reports have been issued,[1] and since these reports are available at the Commonwealth Department of Trade and Customs for anyone defraying the postage thereof, it is necessary for me to state only the essential facts and the details can be filled in by anyone who is sufficiently interested to refer to the reports themselves.

In dealing with this investigation from the Australian point of view, there were two chief problems to be solved. First and most urgent considering the loss sustained, it was necessary if possible to prevent the development of the trouble during shipment overseas. Second, to prevent the development of the disease in the orchard while the fruit was still growing.

## BITTER PIT IN RELATION TO COLD STORAGE

After several years' experiment, the first problem was satisfactorily solved, and apples and pears can be carried to the other side of the world and reach their destination in the same condition as when put on board ship. It has now been determined that this immunity from disease not only applies to bitter pit, but from the nature of the process, the fruit is kept in a state of suspended animation so that no change occurs and no other injurious disease develops. It has also been settled by actual experiment how long the fruit retains its immunity after being removed from cold storage, so that there is sufficient time to market the fruit before deterioration occurs. All the details are given and the precautions to be taken as regards the picking of the fruit, etc., in the published reports.

The essential part of the process is stated by Keeble[2] as follows: "As the result of experiment, he shows that if apples be stored at a temperature of about 30° or 32° F. and if fluctuations beyond these limits be prevented, no bitter pit manifests itself during a period sufficiently pro-

[1] McAlpine, D. Bitter pit investigations. Progress Report **1**: 1–197 1911/12; **2**: 1–224. 1912/13; **3**: 1–176. 1913/14; **4**: 1–178. 1914/15; **5**: 1–144. 1915/16.

[2] Keeble, F. Bitter pit. Nature **98**: 137–138. 1916.

longed to transport the fruit from Australia to Europe. This is a great gain" . . . It is very encouraging to find that this method is at last being adopted in Australia in the numerous cool stores dealing with apples and pears. The oversea shipments of these fruits are also being carried out on the principle laid down and the best evidence of practical success lies in the condition in which such consignments are landed. I need hardly point out that the same principle may be applied to other fruits which have hitherto failed to carry when the freezing point of such fruits has been determined.

### CAUSE OF BITTER PIT

Before dealing with preventive measures in the orchard, it is desirable to state briefly what we know as to the cause of the disease. It would have simplified matters immensely if any definite organism had been discovered, but careful and continuous investigation has shown that insects, fungi and bacteria must be excluded. The theory that spraying with poisonous materials, such as arsenate of lead, is responsible for bitter pit has been definitely disproved. In seeking for the cause, we are therefore thrown back upon the structure and working of the tree, and more particularly of the fruit, where the disease manifests itself.

From the point of view of bitter pit, the most important structure in the apple or pear is the continuous vascular network immediately beneath the skin, where bitter pit originates. This network is discernible even in the very youngest stages of the fruit. It forms the boundary between the pulp and the skin, and has the important function of regulating the supply and distribution of the sap, to nourish the increasing pulp cells and the expanding skin in the growing apple or pear. We can now understand why this regulatory system of vessels exists, and how if it is interfered with in any way, a derangement of the tissues takes place. Wherever bitter pit occurs this vascular network is ruptured and the pulp cells there have become brown and dry, resulting in the consequent falling in or depressions in the skin which constitute the external symptoms of the disease.

We can now picture to ourselves how bitter pit originates. When there is an extra rush of sap, following on dry conditions, the rapidly swelling pulp cells at the external boundary burst the vascular network at localized spots, and the sap pressure which is sufficient to rupture the enveloping network, also bursts the thin-walled pulp cells at these particular spots and death of the cells ensues. Briefly, it may be stated that rapid alternations between dry and moist conditions, combined with fluctuating temperatures, during the growing stages of the fruit, is the exciting cause of bitter pit. Hence, the inherent difficulty of the task

of preventing bitter pit in the orchard in a locality subject to such fluctuating conditions of humidity and temperature.

### PREVENTIVE MEASURES

It will be readily understood from a consideration of the causes which produce bitter pit that there is no royal road to its prevention in the orchard. Light pruning in contrast with severe pruning was shown to reduce the amount of disease considerably; and in irrigated areas a light watering throughout the season, instead of a heavy watering towards the end of the growing period has beneficial results. It was recognized at an early period of the research that there were three main lines of investigation worthy of being followed as a probable means of minimizing the pit:

(a) Experiments with different stocks.

(b) Crossing liable and non-liable varieties.

(c) Breeding of bitter pit-proof varieties by selection and crossing.

(a) *Experiments with different stocks.* The question of the best stocks to use for fruit trees is constantly cropping up and the Australian orchardist is very desirous of scientific guidance in the matter. At the recent meeting of the Australian Association for the Advancement of Science in Melbourne a paper was read on "Apple-tree Stocks," and as showing that this important branch of fruit-growing has not hitherto been made the subject of exact experiment it was strongly urged that the matter should be made the subject of investigation. The "blight-proof stock" is used for apples and it seemed desirable to test the possibility of a "pit-proof stock," that is to say, stock and scion so intimately knit together that the "flow of sap" is regulated and controlled. There is one direction in which the stock undoubtedly affects the scion and that is in the supply of water. This fact may have an important bearing on the pit problem, and it was clearly shown in an experiment where varieties of apple on Winter Majetin stocks required artificial watering while the same varieties growing alongside on Northern Spy stocks were luxuriant and thriving, without any artificial aid. Of course the varieties were all of the same age. In the first year of the investigation, 56 apple trees, mostly susceptible varieties, were budded or grafted on a number of different stocks and planted in a bird-proof enclosure. These were practically all treated alike and the primary object was to test the effect of the stock on the tree, as regards bitter pit in the fruit. Other points of interest were observed at the same time, such as the effect of the stock on time of flowering, on fruiting, on the vigour of the tree, etc., but the main points to be determined were, which stocks were associated with the least amount of pit, the largest yield, and the most vigorous tree. In

the last year of the experiment when the trees were five years old, i.e., from the date of planting, there were great variations in the yield as might be expected. Cox's Orange Pippin topped the list with a yield of 173 apples, and it was interesting to observe that the same variety growing alongside only yielded 7 apples. In the case of the small yield, the stock was Winter Majetin and none of the apples were pitted; while in the case of the large yield, the intermediate stock was French Paradise on Spy roots and there was 44 per cent of pit. The small yield of fruit and the poor growth of the tree indicated that the Winter Majetin stock was evidently unsuitable under the given conditions. When this stage was reached, the experiments were abruptly stopped, in spite of the representation of practical fruit growers who contended that at least ten years wou'd be necessary from the date of planting to test the influence of the stock on the amount of bitter pit. Fortunately, however, a valuable series of stock experiments were being carried out by Mr. Quinn, at the Government Experimental Orchard, South Australia, and these are still being continued through the agency of that State.

The results for the past season are just to hand, and since the trees are now in full bearing, the evidence is beginning to accumulate as to the value of this means for minimizing the prevalence of bitter pit. The report states: "There is some slight evidence to indicate that the use of an intermediate stock between the Spy, the Winter Majetin, or Cole's blight-proof roots, tend to diminish the prevalence of bitter pit in the fruit. But a great number of crops will require to be harvested before any pronouncement can be made in this respect."

At the Burnley Horticultural Gardens, Victoria, there were various other stock experiments initiated. For instance, Cleopatra (syn. Ortley), which is very liable with us, was budded and grafted on to the pear stock. This stock was chosen because the pear was generally free from the disease in this particular locality. Crab stocks were also used. In order to make certain that the seedlings used were from wild trees, I had pips sent out from Britain along with stocks of the wild crabapple. The seeds were planted in a cold frame and produced vigorous seedlings.

(b) *Crossing liable and non-liable varieties.* A beginning was made by taking a susceptible variety such as Cleopatra and crossing it with a comparatively non-susceptible variety such as Yates. It may be noted that both these varieties are of American origin and have been imported here. The seeds of the resulting cross were sown in a pot, and the one plant obtained was planted out.

(c) *Breeding of pit-proof varieties by selection and crossing.* The breeding of perennial plants, such as fruit trees, is a big undertaking and involves a considerable amount of time, in order to reach results of com-

mercial value. But just as breeding stations for annual plants, such as wheat, have been established, so it is becoming more apparent that fruit trees must receive similar attention, not only for the production of new and better varieties than those at present cultivated, but for the scientific treatment of various serious diseases to which they are subject. And there is no disease for which it is more necessary to alter the constitution of the tree than that of pit. It is appropriately called a constitutional disease, since the root of the trouble really lies in the artificial nature of our modern apple. When one considers that the plump succulent and sweet cultivated apple has been derived from the small and sour crab, and that in this process the hardy nature of the ancestor has been sacrificed, particulaıly in the direction of a softening of the fibre, it must be confessed that the penalty paid for the increased attractiveness is a weakening of the constitution. It is only by systematic breeding that a type of apple can be secured with suitable arrangements for the preservation of moisture in dry air and for resisting sap pressure in moist air; and I am fortified in this conclusion by the recommendation of Luther Burbank: "From your report (on bitter pit) I am more than ever convinced of what I have long believed, that all fruit diseases and defects must in the end be *bred out* of them, rather than combated in varieties which are susceptible *to* them."

I have given this brief summary of a very extensive investigation in the hope that it may induce those who are already engaged in the scientific investigation of fruit tree stocks, or in the breeding of new varieties of fruit trees, to give attention to this particular disease in apples and pears, while carrying out their general plan. It is only by the cooperation of various workers that such a constitutional disease can be thoroughly understood, and the means of preventing or minimizing it discovered.

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# A NOTE RELATIVE TO THE RECENT APPEARANCE OF THE SUGAR CANE DOWNY MILDEW IN THE PHILIPPINES

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The disease of sugar cane caused by the conidial Sclerospora, *S. sacchari* Miyake, and known by such names as leaf-stripe disease, Queensland (or Australian) leaf-stripe, cane-dew fungus, and downy mildew of cane, has had an interesting history. Although this disease occurred and was recognized as a disease in Queensland, Australia, in the Fiji Islands, and in Formosa as early as 1909, no published reference to it was made until June 1911. At that time Lyon (3) briefly mentioning the disease as a "leaf-stripe disease" of sugar cane, described the characteristic striping of the leaves and sheaths, and the conspicuous abnormal elongation of the stalks which he illustrated with a photograph, and characterized the disease, of which the cause had not then been accurately determined, as a "quite infectious and quickly fatal" one, that might at any time become a "very serious factor in the sugar industry of Fiji." In March 1912, Miyake (5), who had been studying the disease since 1909 when it appeared at the Formosan Sugar Experiment Station in plots grown from cuttings imported from Queensland, published a detailed report of his work and established the causal fungus as a new species, *Sclerospora sacchari*. His paper was a very comprehensive one, discussing at length the symptoms of the disease, the nature, relationships, and effect of the causal fungus, his experiments on its means of infection and spread, and the progress of attempts to control it in Formosa. Unfortunately, the bulletin was in Japanese and so was unavailable to most pathologists. In November 1913, however, Ito (2) briefly mentioned Miyake's paper, giving a Latin diagnosis of the causal fungus, and urging that a new sub-genus be established to include this and other Sclerosporas in which the conidia when germinating, form tubes instead of the zoospores which characterize the generic type. In April 1915, Lyon (4) gave in English a valuable account of the disease based on a translation of Miyake's article, supplemented by his own experience with the disease in Fiji and Queensland, and by information and material received from Mr. D. S. North of the Colonial Sugar Refining Company who had observed the activity of the disease in both these regions. Alarmed by an increasing knowledge of the menace of this disease, the Federal Horticultural Board of the United States Department of Agriculture decided to take further precautions to protect the

United States in addition to the earlier Quarantine Orders 15 and 16 which prevented the importation of sugar cane from any foreign country and from Hawaii and Porto Rico. Accordingly, as Miyake in Formosa had found that the disease was as destructive to maize as to cane, and hence might be introduced on that host also, the Federal Horticultural Board in July 1916 established Quarantine No. 24 which broadened the prohibition of an earlier order (Quarantine No. 21 of March 8, 1915, preventing the importation of maize from parts of the Orient harboring dangerous maize mildews) and prevented the introduction of maize or related plants from oriental countries where the disease was known or suspected to exist.

In view of the fact that this disease was known from such important cane-growing centers of the Orient as Formosa, Queensland, and Fiji, the writer, while in the Philippine Islands from May 1918, to March 1920, made a careful search for it there but in vain. In the Island of Cebu the writer encountered one sugar-cane clump which had been infected by a conidial Sclerospora (*S. spontanea*) from a badly infected cornfield nearby (6). Also while searching in the mountainous interior of Luzon for the oogonial stage which he believed might occur on sugar cane or its wild relatives at that higher altitude, the writer in January 1920, found an oogonial Sclerospora which was severely injuring the native-grown sugar cane at Bontok, and made the first collections of this fungus, which hitherto had been unknown in the Philippines (6). No instances of infection by *Sclerospora sacchari* were noted, however, although this disease was searched for with care over large areas of cane-growing country from the Visayan Islands in the south to the northern part of Luzon.

Obviously it was a matter of vital importance to the valuable sugar industry of the Philippines that the islands should continue to keep out this dangerous disease from which at the time they were so fortunately free. While returning to the United States in April 1920, however, the writer learned from Mr. C. W. Hines, formerly of the Philippine Islands Bureau of Agriculture, that a Japanese company owning a large plantation near Manila, had imported a short time before over 70 sacks of sugar-cane cuttings from Formosa to use for planting; and that the Philippine Bureau of Agriculture not only had permitted this importation but had secured from the Japanese company a number of cuttings of several desirable varieties for propagation and subsequent distribution. Alarmed at the strong probability that the Formosan downy mildew might thus be introduced into the Philippines, the writer in November 1920, sent this information to Mr. H. Atherton Lee, who had recently been appointed as pathologist with the Philippine Bureau of Agriculture, and

urged that plantings from these cuttings be watched for the possible development of downy mildew. In January, 1921, Mr. Lee replied that no Sclerospora had appeared as yet, but letters recently received (written April 28 and May 12) bring the disquieting information that a conidial Sclerospora has appeared on Formosan cane on the Japanese plantation at Payatas, Rizal Province. Although Mr. Lee has made only a preliminary study of the causal fungus itself, and has devoted his efforts primarily to eradicating the disease, the evidence is strong that the downy mildew is none other than *Sclerospora sacchari* Miyake, which has thus been introduced from Formosa and started in the Philippines. In his letter of May 12, Mr. Lee says, "The conidia of the Payatas cane mildew are not elongate, as in the case of *S. spontanea*, they are more oval with ends more sharpened than smoothly rounded. Moreover, . . . our cane mildew has been found only on the imported Formosan canes. Native cane fields on three sides of the Formosan cane have so far been absolutely free from infection."

The situation has two important aspects. In the first place, the fact that the disease occurs in the Philippine Islands is of considerable interest to other sugar-growing countries. To them, the history of the introduction of this disease into the Philippines teaches a valuable lesson in that it shows how easily the disease may enter a country in spite of inspections and other precautionary measures. As Mr. Lee remarks in a manuscript note[1] enclosed in his letter of April 28, "The sugar cane points, according to the Japanese firm, had been grown by the experiment station of the Japanese Government in Formosa," where they had been dealing with the disease since 1910, and would be best qualified to select healthy cuttings. Not only this but, as an added precaution, the cane was allowed to enter the Philippines only "after dipping in Bordeaux mixture." Furthermore, it was early in 1920 that the cane was imported and planted, but although "upon the appointment of the writers (Mr. Lee and Mr. Medalla) to the plant disease laboratories in March 1920, they became cognizant of these circumstances, and since then, periodical inspections of the plantings have been made," it was not until "April 1921, the cane having been ratooned (that) numerous cases of etiolation of the young plants were observed." The circumstances of this introduction, as well as those attending the introduction into Formosa [cf. Miyake (5) and Lyon (4)], show that the disease is an especially dangerous one; because it is carried in cuttings, and is so insidiously persistent in cane as to make selection of healthy cuttings extremely difficult even where the disease is recognized; because it is almost impossible to detect in cuttings on inspection, and is unaffected by their treatment with Bordeaux; and

[1] Published in Science, N. S., **54**: 274–275. Sept. 23, 1921.

because in developing cane the disease for a long time remains latent or at least sufficiently obscure as to escape notice. A full realization of the manner in which this disease has invaded the Philippines may afford other cane-growing countries a basis for quarantine restrictions and other methods of protection. As far as the continental United States is concerned, little anxiety need be occasioned by this new development in the cane disease situation; because existing quarantines provide ample protection, and because the procedure by which desirable new canes are introduced by the Department of Agriculture provides that cuttings be grown in quarantine greenhouses under surveillance long enough to be quite sure the resulting plants are healthy before they are released. Provision should be made, however, so that no chances may be taken of introducing the disease from the Philippines into Guam, the Virgin Islands, Porto Rico, Haiti, the Dominican Republic, and the Canal Zone, or any other cane-growing regions which are not adequately protected by existing measures but with which the United States is concerned in a controlling or advisory capacity.

The second important aspect of the situation is that the establishing of the disease in the Philippines constitutes a grave menace to the sugar industry of the islands. In the agriculture of the Philippines, sugar cane is a major crop, and the sugar industry is very important financially, the value of the investments involved in the crop (which was worth $32,231,-404 in 1919) being considerable. The previous history of this downy mildew in Formosa indicates that in the Philippines also it probably will prove to be a serious factor. In Formosa, by a most stringent eradication campaign enforced by the Government, the downy mildew was reduced to a minimum on sugar cane; but it spread to maize and proved to be even more destructive to this host, with the result that attempts to control it were opposed by practically unsurmountable obstacles. It seems highly probable that in the Philippines the problem of controlling the downy mildew will be a serious one. Not only is maize exceedingly common throughout the islands, but teosinte (which Miyake inoculated with equal ease) is grown occasionally; while everywhere throughout the length and breadth of the archipelago are found at least two species of wild Saccharum and several other grasses so closely related to sugar cane that it seems inevitable some of them will prove susceptible to the disease. On the other hand, it is possible Philippine conditions may be such that spread of the disease from sugar cane to maize may not readily take place there. Professor W. L. Waterhouse of the University of Sydney has informed the writer that, although he has seen the downy mildew on sugar cane in both Queensland and Fiji, he has never seen maize attacked by it in either of these localities despite ample opportunity for such inocula-

tion. Moreover, although the disease is probably still present in those regions, it has not caused sufficient devastation to occasion published notice, nor has it, if Haywood's account (1) may be relied upon as conclusive, spread so widely as to extend from Queensland to the sugar cane growing coastal strip of northern New South Wales.

In the Philippines the difficulty of control, besides being aggravated by the presence of alternate hosts, will also be increased by the fact that cane for the most part is not concentrated in large easily-controlled holdings, but is grown in small areas by many independent planters, large numbers of whom contribute to a single "central" mill. For this reason and because of the nature of the government in the islands, absolute government control of the disease situation such as was practiced in Formosa, will be impracticable in the Philippines.

Fortunately, however, the potential menace of this outbreak of sugarcane mildew in the Philippines is well realized there, and since Mr. Lee has begun an immediate and drastic campaign of eradication while the infection is still confined to a few localities, there is every hope that by vigorous efforts the rapid control or even complete eradication of the disease may be accomplished.

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## PHYTOPATHOLOGICAL NOTES

*Plant disease survey of England and Wales.*—That there is in existence a plant disease survey of England and Wales which publishes an annual report may not be generally known to pathologists of North America. The publication is issued by the Ministry of Agriculture and Fisheries located at 10, Whitehall Place, London, S. W. I. The title of the latest report is "Report on the Occurrence of Insect and Fungus Pests on Plants in England and Wales for the Year 1919." It is a modest pamphlet of 68 pages. It is known as Miscellaneous Publication No. 33. Similar reports for 1917 and 1918 have been issued. They are Miscellaneous Publications 21 and 23.—PERLEY SPAULDING.

*Summer meeting of the American Phytopathological Society.*—The annual summer meeting of the American Phytopathological Society was held at St. Paul, Minnesota, and Fargo, North Dakota, July 19 to 22, inclusive, in conjunction with the conference of cereal pathologists. There were present as guests of the Society, Dr. E. J. Butler, Imperial Bureau of Mycology, London; Dr. Kingo Miyabe, professor of botany and director of the Botanic Garden, Hokkaido Imperial University, Sapporo, Japan; Mr. R. J. Noble and Mr. James P. Sheldon, Department of Agriculture, New South Wales, Australia.

Prof. A. Jaczewski, director of the institute of mycology and phytopathology, Petrograd, Russia, and Prof. N. I. Vavilov, Bureau of Applied Botany and Plant Breeding, Petrograd, Russia, arrived in America too late to attend the conference. They made an extended tour of the United States and Canada before returning to Russia.

There were present members of the Society from the Philippine Islands, Saskatchewan, Manitoba, and Ontario, Canada, and from the following states: Minnesota, Wisconsin, North Dakota, South Dakota, Kansas, Nebraska, Indiana, New York, Delaware, and District of Columbia.

The days were fully occupied with visits to the experimental plots on the station grounds and the evenings with round table discussions. The following subjects received special consideration at the conferences: Root and ear rots of maize; downy mildew of maize and cereals; root rots and "take-all" of cereals; flag smut of wheat; barberry eradication; wheat rust investigations.

Owing to the very dry and hot weather of the preceding weeks the experimental plots were farther advanced than usual and some of them were ready for harvest. Stem rust was not abundant but was present in

sufficient amounts to show the difference between the susceptible and resistant varieties of wheat. Stem and root diseases of cereals were found plentifully in both localities.

The local committees at St. Paul and at Fargo made excellent provision for the comfort of the visitors and afforded every facility for a profitable and enjoyable meeting. Appropriate resolutions were adopted to express the appreciation of the visiting members.

In view of the report on the status of barberry eradication a resolution was adopted endorsing a vigorous campaign to hasten the work.

The first Cereal Disease Conference was held at St. Paul six years ago At this first meeting Dr. F. Kölpin Ravn was an honored guest. In view of this a letter was drafted and ordered sent to Mrs. Ravn to express sympathy at the untimely death of her distinguished husband.

*Bibliographie der Pflanzenschutzliteratur. Das Jahr 1920.*—This is a new indexing periodical issued by the Biologische Reichsanstalt für Land. und Forstwirtschaft in Berlin-Dahlem. The number for 1920 is the first one issued but there is to be another for the years 1914 to 1919. Hollrung's Jahresberichten über das Gebiet der Pflanzenkrankheiten was discontinued with the number for the year 1913 and the present less pretentious publication takes its place. A casual inspection and comparison of the two publications does not show to the writer any essential difference between the fields covered by the two. The Bibliographie is purely an indexing organ and is in slightly more compact form than Hollrung's Jahresbericht. The former contains 71 pages and approximately 1800 references as compared with 2360 references in the last number of the latter. The arrangement of the material is somewhat changed but is even more usable than the old. The publication is intended as an exchange organ; its price when sold is unknown to the writer. The same institution is beginning the publication of an 8-page folio monthly entitled "Nachrichtenblatt für den deutschen Pflanzenschutzdienst."—PERLEY SPAULDING.

*Citrus canker in the Hawaiian Islands.*—Citrus canker has been found in two orchards in the Hawaiian Islands. One of these orchards is located in Honolulu, Island of Oahu, and the other at Kilauea, Island of Kauai. Citrus growing is of very minor importance in the Hawaiian Islands and such species and varieties as are commonly grown are not extremely susceptible. For these reasons it has not been considered advisable to recommend the application of the Florida methods of eradication of this disease. It seems desirable, however, to call attention at this time to the presence of the disease in Hawaii in order that the fullest protection for the citrus industry of California and the southwestern states may be obtained.—H. L. LYON and H. ATHERTON LEE.

*Sclerotium rolfsii on velvet beans.*—Specimens of velvet beans attacked by *S. rolfsii* were recently received from Altamaha, in southeastern Georgia, showing the characteristic symptoms of this rather general disease on a hitherto unreported host. The trouble was reported as new to the neighborhood where it was found. The plants killed by the disease occurred promiscuously in the field and not continuously in the rows. The leaves of the affected plants were dead, dry, and brown, and the stems almost coal-black. On the main tap root the weft of fungus hyphae extended 2–4 inches below the surface of the soil and about ½ to 1 inch above. On most plants considerable mycelium was present on the outside of the stem and roots, and in some cases sand was held around the stem by the mycelium, forming a very noticeable enlargement. Several to many round, white to brown sclerotia about the size of mustard seed were found on some plants. The sclerotia were produced at numerous points but more abundantly just above the soil surface (Fig. 1).—W. W. GILBERT.


FIG. 1. Velvet bean plant killed by Sclerotium rolfsii: Note abundant weft of mycelium white above, brown below with numerous white immature sclerotia in area indicated by X.

*Disinfecting laboratory cutting instruments.*—In an article entitled "Field Cultures of Wood-Rot Fungi on Agars"[1] Bessie E. Etter recommends heating the scalpel or scissors red hot before each inoculation. The writer has employed this method but it was unsatisfactory because the scalpels were soon made worthless from heating. In making isolations of organisms from fruits he has employed the following method very successfully:

After scraping off any debris which may be adhering to the surface of the cutting tool, the tool is plunged into a wide-mouthed bottle of 90 per cent ethyl alcohol in which it is left a minute or more and then the alcohol burned off but care being exercised not to heat the tool enough to injure it. Christiansen[2] found that one-half a minute was sufficient time for disinfection to be accomplished with 70 to 90 per cent ethyl alcohol, the lower and higher percentages of alcohol requiring a somewhat longer time.—J. S. COOLEY.

[1] Phytopathology, **11**: 151–154. 1921.

[2] Johanne Christiansen. Zue Theorie und Praxis der Alkoholdisinfektion. Zeitscrift für physiologische Chemie. Hoppe-seyler **102**: 275–305. 1918.

*Sunburn and tomato fruit rots*[1].—The sunburn of tomatoes is very common on fruits which are more or less exposed to the sun during very hot weather, and is especially severe on fruits where the vines have been defoliated by *Septoria lycopersici* or other causes which results in their exposure to the sun. Sunburn is most severe on fruits which are approaching maturity and just beginning to color. The sunburnt area does not assume the normal red color of a ripe fruit but takes on a slightly reddish yellow. The varying amount of red and yellow in the sunburnt areas depends on the ripeness of the fruits at the time of injury.

These sunburnt areas develop numerous very small, light brown spots which are referred to by the growers as "freckles." In the beginning, these spots are mere pin points but they increase in size, become black and finally rupture, releasing great numbers of spores of Alternaria. These spores are extremely variable in size but a very large number of them show characters which justify classification as *A. solani* (E. & M.) J. & G. In some cases these spots rupture when about ¼ inch in diameter while in other cases they coalesce and cover practically the entire sunburnt area. (See figures 1, 2, and 3).

The question very naturally arises as to whether these spots are due to the pathologic condition resulting from the sunburn or to the fungus which is found growing in them. A large number of sunburnt tomatoes were gathered, wrapped separately in paper and brought into the laboratory. These were grouped with reference to the size of the spots into groups a, b, c, d, group "a" having the smallest and group "d" the largest spots.

The epidermis was peeled back and cultures prepared by touching a sterilized needle to the pulp below the spot and then to the agar in a petri dish. These cultures gave no growth from group "a," good growth from most of group "b" and from all of groups "c" and "d" indicating that the spots were formed in advance of the infections.

Pure cultures of the organism were applied to the uninjured surface of sunburnt areas and to the surface of normal ripe fruits; also to the surface of normal ripe fruit in which the epidermis had been punctured with fine sterilized needles. The checks consisted of the same kinds of fruits but they were not inoculated. In all cases the surfaces of the fruits were sterilized before puncturing and before inoculation. Of course, it was impossible to determine whether these fruits had been infected before gathering or not. The results of these tests indicated that the organism attacked fruits that had been injured by sun burn or by puncturing with a needle very readily but that it attacked the normally ripened uninjured fruits very slowly.

[1] Paper 62 of the Journal Series, New Jersey Agricultural Experiment Stations, Department of Plant Pathology.

This was followed by a study of the epidermis of the spots as compared with the epidermis outside the spots. These studies showed, 1. that the spots were due to a discoloration of the epidermal cells and that these spots could increase in size in the sunburnt areas indefinitely regardless of the presence or absence of the organism and, 2. that this was followed by a pulling apart or slight rupturing of these darkened cells. This very naturally produced most favorable conditions for natural inoculation with the spores of the fungus.

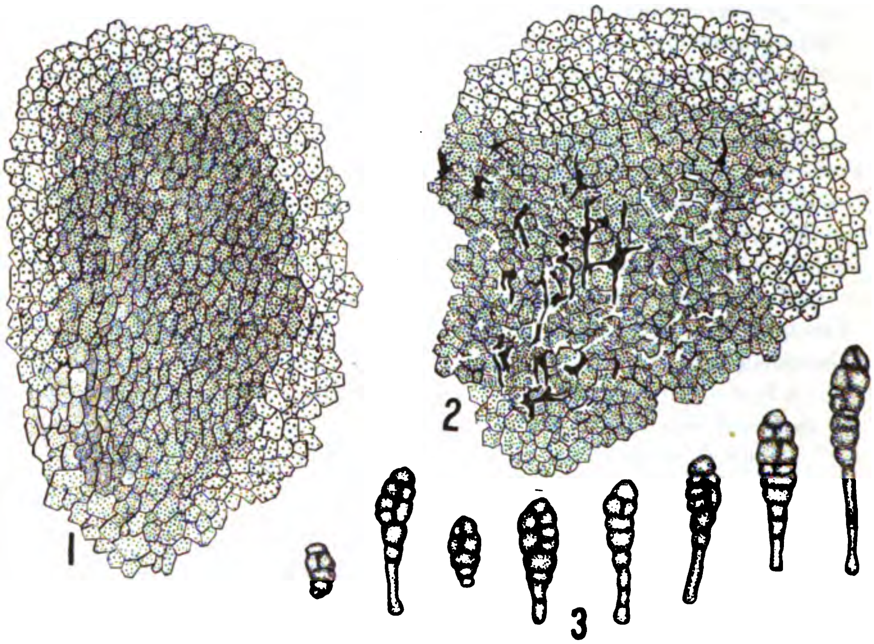


FIG. 1. Brownish spot on sunburnt fruit before rupturing of the epidermal cells.
FIG. 2. Spot on sunburnt fruit showing the rupturing of the fruit.
FIG. 3. Spores from the infected spots. Drawings by Miss G. E. Macpherson and Mr. G. W. Fant

These studies indicate that sunburnt fruits are far more susceptible to fungus injuries than normal ripe fruits; and that the fungus gains entrance thru wounds, in this case ruptures in the epidermis which are the direct result of sunburning. This organism also infects the fruit cracks and causes rottings which result in great losses.—MEL T. COOK.

*Leaf curling in tomatoes.*—The accompanying illustration represents very clearly a phenomenon assumed by some tomato plants, about which inquiries have become very numerous of late years. (See figure 1).

Some years ago (in 1916) I observed this phenomenon in plants growing in Lethbridge, Alberta. Since then on numerous occasions my attention has been called to it. Indeed, European literature has dealt several times with apparently the same phenomenon.

The curling of the leaves is confined to plants grown as single stems and tied to stakes or other supports. It occurred in all varieties under observation,—Earliana, Bonny Best, Chalk's Jewel, Livingstone Globe,

FIG. 1. LEAF CURLING IN TOMATOES

John Beer, as well as in the yellow pear-shaped tomatoes, provided these plants are trimmed to one shoot. Last year records were kept of the yield of these plants. To begin with, the setting of the fruits was perfect, as near a complete set of fruits was observed as possible. The fruits were perfect in size and shape, and the yield very large. No injurious

influence was discovered. It was immaterial whether the plants trimmed to a single shoot were trained to stakes or left growing on the ground. Three rows of several varieties of tomatoes were planted out from seeds saved from plants showing pronounced curling. Every other plant was pruned throughout the season to one stem, the remainder were allowed to grow as they pleased. The effect was remarkable in as much as every pruned plant showed pronounced leaf curling, which was entirely absent in the unpruned plants. The comparative yields obtained were uniformly satisfactory in the pruned and unpruned plants. This year the same observation was made. The excessive and prolonged drought did not enhance the symptoms over the previous year, which was almost excessively wet.

The phenomenon is most pronounced; inquiries were received from many parts of Canada, and in all cases it was found that the plants were pruned to one stem. Correspondents stated that the yield was quite good. Nowadays one has become quite alarmed at noticing rolling of leaves in plants. This is no doubt due to the attention which leaf roll in potatoes has received. Indeed, the curl in tomato leaves resembles potato leaf roll very closely, especially in the firm succulent nature of the curled leaves. Anatomically the leaves of affected tomatoes resemble the structure with which we have become familiar in potatoes. The abundance of starch is remarkable in the curled leaves of both plants.

It was sought to determine whether mere increased "root pressure" could cause the curling. A carefully devised and checked experiment revealed that increased root pressure was well taken care of by the corresponding activity of the hydathodes of the leaves. No curling resulted, although the leaves were very firm, rigid and succulent. Eventually owing to lack of sufficient nourishment, the plants succumbed. It was thought that the removal of the side shoots diminished the area of the plant to such a degree that the ascending sap of a normal root supply might result in a mechanical curling of the leaves. The experiments conclusively showed this not to be the case. One observer (Poser, C. Gartenwelt **24**: 181. 1920) believes that the curling is due to excessive and sudden ventilation, which on correcting, prevented progress of the "disease." This must have been a wilting of greenhouse grown plants (as they were) when exposed to drafts of air.

Schoevers, T. A. C. (Tijdschr. over Plantenziekten **25**: 11-12, 1919) states that "pruning and stopping back" reduce development, hence the transport of reserve food materials from leaves to fruit is interfered with. This causes the non-parasitic rolling."

We have come to exactly the same conclusion. The phenomenon is not a disease, it does not interfere with the yield and quality of fruits

but it would indicate that tomato plants might well be pruned to two or three shoots, if it were proved that such method would give an increased yield.—H. T. GÜSSOW.

*A "dry rot" disease of alfalfa roots caused by a Fusarium.*—The pathogenicity of a root disease of alfalfa which is of considerable consequence to southern Utah and possibly to Arizona also, has been traced to the activity of a Fusarium. This fungus causes brown cankerous depressions to appear at the base of lateral roots, which it entirely destroys, and infests both the parenchymous tissue and xylem vessels of the tap root. The disease is most active during the hottest period of the summer and is apparently confined to hot dry localities. Plants attacked by the fungus wither and die with remarkable suddenness. The disease first manifests itself by a few dead or dying plants which soon become conspicuous in a green alfalfa field. These plants are centers from which the infection spreads in various directions, often destroying an entire field within a single season. Infected areas vary in size from a few feet to several rods in diameter, but always present a very striking and characteristic appearance. They are usually somewhat circular in outline and have at their outer margin an active zone about three feet wide which separates green, healthy appearing alfalfa from the black, decayed plants which have been killed by the disease. The outer margin of the zone is marked with plants just beginning to wilt. Back of these toward the devastated area are plants green but dry, indicating sudden death. The plants that form the inner rim of the zone are bleached to a straw color. Specimens of alfalfa roots recently received from Arizona gave positive evidence of the presence of a Fusarium similar to, if not identical with, the fungus which causes "dry rot" in southern Utah.—WALTER P. COTTAM.

*Personals.*—Dr. E. J. Butler, chief of the Imperial Mycological Bureau located at Kew, England, has been taking part in the Cereal Pathologists' Summer meeting. While in Washington, a smoker and lunch was held in his honor, thirty-two pathologists participating. In an informal talk Dr. Butler explained in some detail the aims and scope of work tentatively proposed for his Bureau. It is a coordinating central office maintained by the British Colonies for strengthening their work on plant diseases. Nearly sixty investigators are included in its field. Some of the lines of work started or shortly to be undertaken are: Correlation of projects, so that each worker may know who is engaged upon a certain problem; collection of literature so as to furnish a worker with a copy, a summary, or a translation of a desired paper which is not available to the person needing it; identification of specimens; pure cultures of parasitic fungi;

and host and parasite indexes. Dr. Butler desires to promote international relations so far as may be possible.

Miss Rose Bracher of the University of Bristol, England, has been spending the past year studying plant pathology in this country. She is the holder of the Rose Sidgwick Memorial Fellowship given by the American Association of University Women, (formerly the Association of Collegiate Alumnae) in memory of Miss Rose Sidgwick of the University of Oxford who died in this country while engaged in work for the British Educational Mission of 1917. Miss Bracher has spent eight months at the University of Wisconsin, one month at Columbia University, two months in the United States Department of Agriculture, and about two weeks at Guelph, Ontario. She returns to England to take up investigations in plant pathology and in the cytology of Rhytisma.

Dr. A. de Jaczewski of the Forestry Institute at Petrograd is visiting various plant pathological centers in this country. He is endeavoring to reestablish exchange relations with other pathologists and to learn what progress has been made by the outside world during the past six years of his isolation by reason of the war.

H. R. Rosen, Associate Professor of Plant Pathology, University of Arkansas, has been granted a year's leave of absence and will leave Fayetteville in September for the Missouri Botanical Gardens, where he will complete his work on the bacterial disease of foxtail and other grasses.

Dr. Alfred H. W. Povah, formerly Assistant Professor of Forest Botany and Pathology at the State College of Forestry, Syracuse, N. Y., now holds the position of Associate Professor of Plant Pathology and Associate Pathologist in the Alabama Polytechnic Institute at Auburn.

Dr. H. H. Whetzel, head of the department of plant pathology at Cornell University, is taking sabbatical leave for 1921–22 in Bermuda. While there he is associated with the department of agriculture of the Bermuda Islands in developing their plant disease survey and research work. He also acts as pathological inspector for exported plants and plant products.

Dr. L. M. Massey is acting head of the department of plant pathology at Cornell in Dr. Whetzel's absence on sabbatical leave.

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NUMBER 10

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PHYTOPATHOLOGY

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# THE MYCOPLASM THEORY—IS IT DISPENSABLE OR NOT?

JAKOB ERIKSSON

## I. SORI AND MYCELIA OF RUST IN SEEDS

In the year 1911 Pritchard (Phytopath. **1**: 150–154.) and in the year 1913 Beauverie (Compt. Rend. Acad. Sci. Paris, 5 May, p. 1391, and 3 Nov., p. 787) published observations upon the occurrence of groups of rust spores and rust mycelia in American and in French seeds of wheat, barley and several cultivated or wild grasses (Bromus Agropyrum, etc.). The two observers presume that these sori might, after wintering, give origin to a new outbreak of rust in the following year. Two short replies by me against Pritchard in the year 1912 (Centralbl. f. Bakt. Abt. II, p. 453) and against Beauverie in the year 1914 (C. R. Acad. Sci. Paris, **158**: 1194) did not suffice for removing such an idea. In the years 1914 to 1918 Beauverie has continued publishing new articles in the same way (C. R. Acad. Sci. Paris, **158**: p. 1196, Trav. d. Biol. Veg., Paris, p. 11; Bull. Soc. Path. Veg. Fr. **5**: 89).

The most detailed and pretentious of Beauverie's articles is entitled "*Les germes des rouilles dans l'interium des semences des Graminees.*" In this he pronounces the following 4 theses: (1) the existence of mycoplasm is not proved; (2) sori of rust are to be found in the seeds of grasses; (3) these sori are sufficiently numerous; and (4) do these sori transmit the disease from one year to the other?

By the treatment of the three last theses he describes: (1) case of wheat, (2) cases of common barley and of *Puccinia glumarum* and (3) cases of *Bromus mollis* and of Agropyrum. For each of these cases he states the localization of the sori and gives numerous diagrams of seeds that are cut through. Neither in the text nor in the figures can I detect anything essentially new, that has not been mentioned in my book "*Die Getreideroste*" (Stockholm 1896). Also there are no proofs given for the transmission of the rust by means of such sori to the vegetation of the following year. This is also expressed in the following words by Beauverie (l. c., p. 12): "With regard to the thesis 4 ("Do these sori transmit the disease from one year to the other?") our researches and our experiences, though they have been numerous enough, do not permit us to pronounce today a definite answer to the question." In spite of that he can not leave the

hypothesis of transmitting the rust in that way and he discusses how the transmission may take place, either to the interior of the embryo or from the exterior on the young seedlings.

In order to prove the first alternative, i. e., the interior infection of the embryo, numerous experiments were arranged, but the results were "uncertain and insufficient." Beauverie considers the other alternative, i. e., the exterior infection of the young seedling, "much more likely" and he "hopes by means of a fall collection of seeds of barley, containing rust sori, to be able to solve easily the problem the following spring."

The next publication by Beauverie upon this question is dated 1918. There he says, that the occurrence of the "intraseminal" sori varies considerably. They were very common in the years 1913, 1914, 1915 and 1916, but very rare in the years 1917 and 1918. This being the case, the propagation of the diseases by means of such seeds,—"if real?"—can only be "an adventive means" for assuring the perennity of the grain rust.

Thus it seems that the hope, pronounced by Beauverie in the year 1914 as to the definitive solution of the problem, was disappointing. For he does not report on any recent studies made by himself. He only refers to some experiments of Hungerford (Phytopath. 7: 73), performed at Madison (Wisconsin) in the year 1916. But these experiments gave negative results.

Such being the actual status of the question I think we can and must once for all, abandon the idea that the "intraseminal" sori in the seeds constitute a mode of hibernation of the grain rusts. The appearance of sori in grass seeds, is, as already stated by me in the year 1896, only a case of hypertrophic outbreak of the fungi without any importance whatever in their life-history.

## II. THE STRUCTURE OF THE MYCOPLASM AND ITS TRANSITION TO MYCELIUM IN PHYTOPHTHORA INFESTANS AND PERONOSPORA SPINACIAE

While discussing the mycoplasm, the objection has been raised again and again, that I had not given a satisfactory analysis of the morphological structure of this mode of existence and of the transition of the intracellular mycoplasm to the intercellular mycelium. I hope my recent investigations upon the life-history of the late blight of potato (*Phytophthora infestans*)[1] and of the downy mildew of spinach (*Peronospora spinaciae*)[2] may satisfy all reasonable claims in that way.

[1] Eriksson, J. Uber den Ursprung des primären Ausbruches der Krautfäule, Phytophthora infestans (Mont.) de By. auf dem Kartoffelfelde. Ark. Bot., Stockholm, **14**: No. 20, 1916—Cfr. Rev. Gener. Bot., Paris, **29**: (1917) et **30**: (1918).

[2] Eriksson, J. Zur Entwickelungsgeschichte des Spinatschimmels (Peronospora Spinaciae (Grew) Laub.) Ark. Bot., Stockholm, **15**: No. 15, 1918.—Cfr. Rev. Gener de Bot., Paris, **32**: (1920). E. Foëx.

The research upon *P. infestans* was performed in the year 1915 with material of infected potato leaves, collected and imbedded in paraffin for cytological examination, in the years 1905 and 1911.

By the examination of the different zones of a spot on a diseased potato leaf, as seen at the earliest (*primary*) outbreak of the disease, in July or in August, I could follow all the evolution stages of the blight fungus from its life within the cells up until its penetration through the stomata as external mycelium developing aerial spores.

In the peripheric zone of the leaf spot I detected the fungus element, living with the protoplasm of the host cell. The two symbionts formed a colloidal fluid, including minimal granules and particles. The chlorophyll bodies become disorganized and assimilated in the surrounding plasm. The cell nucleus also is dissolved and in the place of it there appear several small nucleoles. Now the fungus element predominates in the symbiosis—this stage has changed to an *antibiosis*—and it is ripe and ready for issuing out from the cellar lumae into the intercellular cavities. It grows out as a plasm tube but this plasm tube soon changes its nature, consituting a mycelial thread. The mycelium develops organs for fructification (antheridia and oogonia). The results of this act become oospores. These are not resting spores, surviving to the next year for propagating the fungus. They are true summer spores, ready to germinate immediately and to produce mycelium on the surface of the plant.

For the research of the life-history of the down mildew of spinach I had at my disposition two different races of spinach, the one infected by the fungus and the other sound. The two races grew in the year 1911 at Experimentalfältet (Stockholm), the distance between the two races being only about 30 meters. On July 18, the first, i. e. the primary, spots of disease were observed on some leaves of the one race, and from that day new spots appeared successively on the same plant bed, while all leaves of the other race on the other plant bed continued to grow clean.

On the day of detecting the first spots, i. e., on July 18, small pieces of leaves from the diseased and from the sound plants were collected and imbedded in paraffin for cytological examination.

In the cells of the sound race I found a normal protoplasm with imbedded normal cell nuclei and chlorophyll bodies. In the peripheric zones of the spots of the diseased race, on the contrary, I detected that the cells were filled with a very roiled plasm between the chlorophyll bodies. These bodies as well as the nuclei became dissolved and assimilated in the plasm and small nucleoles appeared in the symbiotic plasm body. The whole evolution was exactly the same as that which occurred in the potato.

I was able to show, at a magnification of 2500 diameters, the different stages of evolution of the spinach mould in photomicrographic figures, which exclude every subjective construction. In some figures one can see the structure of the mycoplasm in the inactive stage in the infected cell, side by side with the structure of the normal protoplasm in a cell of the sound race. In other figures one can see a more advanced stage of the intracellular mycoplasm, its resting stage with nucleoles. In yet other figures one can see the discharge of the cell contents into the intercellular spaces and so on. The nature of the plasm tubes, just issued, may be seen very distinctly in several photomicrographic figures. If two tubes from two different cells meet one another they merge into one. The plasm tubes are a previous stage of an intercellular mycelium producing a secondary outbreak of the disease.

The diseased race of plants was after some weeks so roughly used by the fungus that the culture had to be pulled up and removed from the bed. The other race of plants grew sound until the ripening of seed. Seeds of this sound race, collected in the autumn of 1911, when grown in the year 1912 on several culture beds gave an exclusively sound harvest of spinach.

### III. APPLICABILITY OF THE MYCOPLASM THEORY FOR OTHER PLANT DISEASES

Owing to my studies with cereal and hollyhock rusts and with potato and spinach blights, as well as on account of observations in the open air upon many other diseases since decades back, I am inclined to suspect the occurrence of a mycoplasm symbiosis in the life cycle of several other plant pathogenes. I mention a number of such: *Puccinia chrysanthemi, P. ribis, P. suaveolens, P. tragopogonis, Uromyces betae, U. alchemillae, Cronartium ribicolum, Phragmidium potentillae, P. subcorticium, Coleosporium campanulae, C. compositarum, Chrysomyxa abietis, Melampsora salicina, Peronospora trifoliorum, P. ficariae, Sphaerotheca mors-uvae, S. pannosa, Microsphaera euonymi, Plasmodiophora brassicae, tobacco mosaic, etc.*

STOCKHOLM

# THE PATHOLOGY OF LUPINUS ARBOREUS, WITH SPECIAL REFERENCE TO THE DECAYS CAUSED BY TWO WOUND-PARASITES—COLLYBIA VELUTIPES AND PLEUROTUS OSTREATUS

ARTHUR S. RHOADS

WITH PLATES XVIII TO XX

## INTRODUCTION

During the winter of 1918 the writer noted that the stems of *Lupinus arboreus* Sims, an arborescent shrub growing naturally on sand dune land in several widely separated localities in San Francisco, were frequently broken down as the result of decay. At various times during the rainy season he observed that *Collybia velutipes* (Curt.) Quél. and *Pleurotus ostreatus* (Jacq.) Quél. were of very common occurrence on stems of this species of lupine, both occurring as wound parasites and as saprophytes on dead stems (Plate 1). The common occurrence of these two wood-rotting fungi as active wound-parasites on this arborescent shrub, which has not been reported previously as a host for either of these fungi, presented to him a new and interesting problem that was deemed worthy of investigation.

## CHARACTERISTICS AND ECONOMIC IMPORTANCE OF LUPINUS ARBOREUS

*Lupinus arboreus* Sims, commonly called the tree lupine or, by some, the yellow lupine, is an evergreen shrub becoming distinctly arborescent; it attains a height of from 4 to 8 feet and a diameter of as much as 4, or rarely 5, inches at the base. It is of common occurrence on sandy soils near the ocean, where, in the spring with its sulphur-yellow flowers in loose racemes often a foot in length, it is very showy.

*Lupinus arboreus* exhibits a great variety of growth forms. Occasionally it has an erect main stem, but more often it consists of several distinct stems which may be erect or nearly so, spreading well apart, or becoming more or less decumbent and sending up erect shoots from these. In its occurrence on an area it may vary from isolated bushes to dense thickets. Economically, *Lupinus arboreus* is of considerable importance as a soil retainer in sand dune country.

### GENERAL PATHOLOGY OF LUPINUS ARBOREUS

*Lupinus arboreus* is a very rapid growing, comparatively short-lived shrub, readily attacked by a number of insects, parasitic fungi, and even animals.

Among the insects attacking *Lupinus arboreus* the most important is the larva of a moth, *Hepialus sequoiolus* Behr.,* whose tunnels the writer has frequently found in the living stem. Williams (12) mentions finding the larva most frequently in the large yellow lupine. He states that the larva bores longitudinal passages just above the ground or a little under, turning its burrow at right angles and usually closing the opening with excrement. He likewise states that *Hepialus sequoiolus* is not rare in the vicinity of San Francisco. A little later Williams (13) mentions finding the larvae in November feeding on the decumbent stems and in the thicker roots of the yellow lupine. In a third article Williams (14) contributes his observations on the life history of *Hepialus sequoiolus*, being chiefly an account of the pupation of the larvae. Williams states that they inhabit only old plants, boring into their thicker portions—sometimes going well into the roots and again ascending into the branches. Usually, however, they are found in the main trunk above or below the ground, a large decumbent stem being a particularly favorable locality for them. He likewise mentions finding in the same lupine stem the larvae of the large noctuid, *Gortyna immanis*, which is quite sluggish compared to *Hepialus sequoiolus*.

The tunnels commonly formed in the living lupine stems by these insects naturally afford excellent points for the germination of fungous spores and for the rapid spread of the mycelium through the stems. It is the writer's opinion that they are by far the greatest contributing cause to the destruction of *Lupinus arboreus* bushes by the two wood-rotting fungi discussed in the present paper.

Concerning the fungi occurring on *Lupinus arboreus*, a number of miscellaneous species of minor importance have been reported by various writers. Of the list enumerated below, all but one belong to the Ascomycetes and Fungi Imperfecti.

Cooke and Harkness (2, p. 16) list *Diplodia lupini* on stems. Phillips and Harkness (9, p. 25) describe *Stictus lupini* as a new species. Harkness (4, p. 44) describes *Diaporthe* (*Tetrastaga*) *lupini* on branches. Harkness (5) lists both *Dialonectria depallens* (p. 173) and *Sphaeria* (*Didymella*) *lupini* (p. 174) on stems. Harkness (6) lists *Stictus decipiens* Karst. on dead stems (p. 264), *Metasphaeria lathyri* Sacc. (p. 267), and *Pleospora leguminum* Rab. on legumes (p. 268); he also lists the following fungi from the Harkness herbarium: *Phoma lupini* (p. 268),

* Determination by Mr. G. F. Ferris of the Department of Entomology and Bionomics of Leland Stanford Junior University.

*Sphaeropsis lupini* (p. 268) *Hymenula lupini* (p. 270), and *Valsa lupini* (p. 270), all occurring on stems. Harkness (7, p. 445) lists *Sordaria languinosa* Sacc. on dead branches. With the exception of *Sphaeria (Didymella) lupini*, which was reported from Sacramento, the remainder of the above fungi were reported from San Francisco.

Farlow and Seymour (3, p. 27) record only the above mentioned species on *Lupinus arboreus*, but include *Macrophoma lupini* Berl. & Vogl. as a synonym of *Phoma lupini* Cke. & Hark., and *Nectria depallens* Berl. & Vogl. as a synonym of *Dialonectria depallens* Cke. & Hark.

To the foregoing list may be added the wood-rotting fungi, *Collybia velutipes* and *Pleurotus ostreatus*, which are of very common occurrence about San Francisco, and whose destructive action on the host is made the basis of this paper. The writer has also found a single sporophore of *Armillaria mellea* growing from the root of a living bush of *Lupinus arboreus*.

An orange-colored canker, caused by an undetermined species of imperfect fungus, is also of frequent occurrence as a parasite on the living twigs. This fungus gains entrance to the twigs through insect tunnels and develops an orange-colored, waxy stroma underneath the bark which, in time, splits longitudinally and recurves from the stem, often exposing more or less of the wood for a length of several centimeters. The hyaline spores, which are mostly 1-septate and falcate at maturity, are developed directly from the orange-colored, waxy stroma.

Among the animal injuries the depredations by mice are of most common occurrence. Their attacks are confined mainly to the smaller stems ranging from ½ to 1½ inches in diameter and usually are made at or near the base of the shrubs.

Even the very form of growth of the lupine bushes is often responsible for considerable mechanical injury. Crotches of the branches frequently split and, in large bushes where the stem branches close to the base, the luxuriance of growth, aided by the ease with which the stems split radially, frequently results in a more or less serious splitting of the stem. The splitting of the crotches and branches is materially augmented by people tramping around the lupine-covered dunes. These split crotches present ideal infection points for the spores of wood-rotting fungi and both *Collybia velutipes* and *Pleurotus ostreatus* were frequently observed fruiting at these points.

## OCCURRENCE OF WOOD-ROTTING FUNGI ON LUPINUS ARBOREUS.

On January 1, 1920, the writer made an intensive reconnaissance of a portion of the lupine-covered sand dunes on the Fort Scott Reservation in San Francisco, in order to secure some idea of the percentage of shrubs

infected by these wood-rotting fungi. It is believed that the results obtained represent a fair average of the conditions existing at the time of the reconnaissance and that the figures will be sufficiently accurate to serve the purpose for which they were intended—namely to give an estimate of the percentage of shrubs bearing fruiting bodies of these fungi. The abundance of the sporophores, of course, may vary greatly from time to time, depending upon the weather conditions. The results of this reconnaissance are given in table 1.

TABLE 1

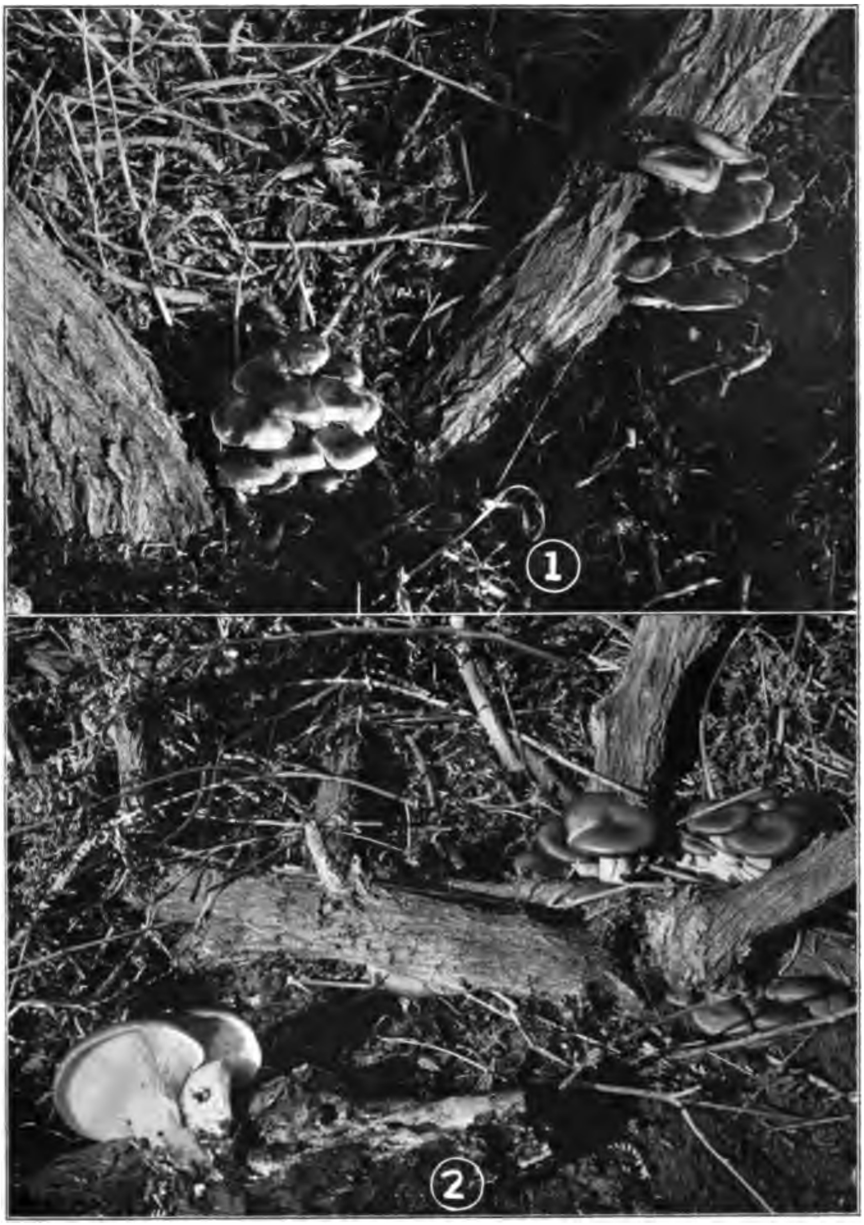
*Number and per cent of Lupinus arboreus bushes on the Fort Scott Reservation in San Francisco bearing sporophores of wood-rotting fungi*

| Fungi | Number | Per cent |
|---|---|---|
| LIVING BUSHES | | |
| *Collybia velutipes* | 130 | 24 |
| *Pleurotus ostreatus* | 25 | 5 |
| *Armillaria mellea* | 1 | 0 |
| Total bushes bearing sporophores | 156 | 29 |
| Total bushes not bearing sporophores | 385 | 71 |
| Total number of bushes examined | 541 | 100 |
| DEAD BUSHES | | |
| *Collybia velutipes* | 26 | 31 |
| *Pleurotus ostreatus* | 5 | 6 |
| Total bushes bearing sporophores | 31 | 37 |
| Total bushes not bearing sporophores | 53* | 63 |
| Total number of bushes examined | 84 | 100 |

* In 23 of these bushes the stems were so badly rotted that they could be broken off by tramping against them. Doubtlessly a large majority of the remaining bushes were more or less rotted by at least one of these fungi.

In the above table, all bushes that had one or more living shoots from the root, were considered as living. The figures for the bushes bearing fungi do not necessarily indicate all of the infected stems, since, in the bushes not bearing sporophores, a number of stems were found to have rotten branch stubs and, when cut into, were found to be decayed within.

Subsequent observations indicated that by January 1 the fungi had attained their maximum fruiting. On January 4 it was noted that many of the sporophores were commencing to dry up, although a few fresh ones were beginning to make their appearance. On January 10, however, but few fresh sporophores of either *Collybia velutipes* or *Pleurotus ostreatus* were to be seen, practically all of them being well dessicated and more or less inconspicuous, especially in the case of *Collybia velutipes*.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In *Collybia velutipes* practically 90 per cent of the sporophores noted on the living bushes in table 1 occurred at the base of the stems, usually growing up from the root crowns (Plate XVIII, fig. 1). By excavating the sand about the root crown the development of the fruiting bodies could be seen readily. The sporophores, which usually occur in dense clusters, originate at some point on the root, often several inches beneath the surface of the ground. From this point, which may be an insect tunnel or the dead side of a root, there develop upwards a number of long attenuated, rhizomorph-like stems in all stages of growth. As a rule all stages in the development of the sporophore can be seen, varying from the slender stems bearing miniature unexpanded pilei that have not yet pushed up to the surface of the ground, to the stouter ones, which, when they reach the surface of the ground, abruptly expand into a stout velvety stem bearing the pileus. Occasional clusters are found where a number of rhizomorph-like stems have anastomosed into a single stem suggestive of the rooting base or pseudorhiza characteristic of *Collybia radicata*. The remaining 10 per cent of the sporophores noted on living bushes in table 1 developed on the stems at borer holes, branch stubs, split crotches, and dead areas at points varing from a few inches to 3 feet above the ground (Plate XVIII, fig. 1). The fruiting bodies that develop on the stems well above the ground lack the long attenuated rhizomorph-like stems and are considerably smaller than those that develop around the root crown where they receive the benefit of the soil moisture. In the dead bushes noted in table 1 all the observed sporophores of *Collybia velutipes* occurred at the bases, usually growing up from the roots underground.

In the case of *Pleurotus ostreatus* approximately 75 per cent of the sporophores noted on the living stems in table 1 occurred at points, such as insect tunnels, branch stubs, split crotches, and dead bark areas, from 1–3 feet above the ground. When developing on the stem, either at the ground line (Plate XVIII, fig. 2), or at points above it (Plate XIX, fig. 2), the sporophes invariably were laterally stipitate, with a poorly developed stem. Occasionally, however, the sporophores would develop from the roots beneath the surface of the ground; in this case they invariably were excentrically stipitate, with a well developed stem. As in *Collybia velutipes*, the sporophores developed up on the stems were much smaller and became desiccated more quickly than those developing at or near the ground line.

On February 21, 1920, after a comparatively long dry period, the writer again visited the lupine-covered sand dunes on the Fort Scott Reservation, to examine bushes of an associated species of lupine, namely, *Lupinus chamissonis* Esch., a blue-flowered species with silvery foliage, which occurs in small quantity there near the ocean. The stems of this

species are distinctly woody; however, they are much slower in growth and do not attain as large a size as those of *Lupinus arboreus*, none being noted that were over 2½ inches in diameter. The shrubs of *Lupinus chamissonis* are densely branched and very bushy, so that an examination of the stems for the presence of sporophores of fungi is quite difficult. However, the writer found three living bushes of this species with dessicated sporophores of *Collybia velutipes* that had developed at split crotches. This record of the occurrence of *Collybia velutipes* as a wound parasite on *Lupinus chamissonis* is also new.

A few days later the writer visited the sand dunes along Sloat Boulevard, near the ocean, where a large area is more or less densely covered with both *Lupinus arboreus* and *L. chamissonis*. Here one area was particularly striking in that practically all the bushes of *Lupinus arboreus* had been rotted by *Collybia velutipes* and *Pleurotus ostreatus*, whereas practically all the bushes of *Lupinus chamissonis* were growing vigorously and in a good healthy condition, only three being found bearing sporophores of *Collybia velutipes*. On an adjoining area, however, where there was practically a pure growth of *Lupinus chamissonis*, several bushes, both living and dead, were found bearing sporophores of *Collybia velutipes*. In so far as could be determined in the case of the living bushes, the sporophores always occurred in split crotches which are largely caused by human agency, there being no evidence of insect tunnels in the stems. Despite his persistent search, however, the writer has not found *Pleurotus ostreatus* fruiting on *Lupinus chamissonis*, although it very likely occurs on it.

In this connection it may be well to mention that, although the writer has collected the wood-inhabiting fungi rather extensively in the vicinity of San Francisco for more than a year, he has never found *Collybia velutipes* on any hosts but the two species of lupine previously mentioned. *Pleurotus ostreatus*, however, is encountered occasionally in the more humid forest sites. It is especially interesting, however, that these two fungi should occur so frequently as wound-parasites on the woody lupines.

On the sand dunes, both at Sloat Boulevard and on the Fort Scott Reservation, *Lupinus chamissonis* appears to be free from the insect injuries which are so prevalent in *L. arboreus* and which, in that species, lead to so many infections by *Collybia velutipes* and *Pleurotus ostreatus*. It also possesses a much tougher wood than *L. arboreus* and, by reason of this in conjunction with its more compact, bushy form, it is much more resistant to the natural mechanical splitting of the branch crotches which, in *L. arboreus*, is another great contributing cause to infection by the above-mentioned wood-rotting fungi. In case a permanent sand dune cover of lupine is desired, it is believed that *L. chamissonis* will prove of

far greater value than the larger, faster growing, but much shorter-lived species, *L. arboreus*, especially where the living shrubs are likely to become infected with such wood-rotting fungi.

### REVIEW OF LITERATURE ON THE DECAYS CAUSED BY COLLYBIA VELUTIPES AND PLEUROTUS OSTREATUS

An extensive literature has been built up on both *Collybia velutipes* and *Pleurotus ostreatus*, particularly on the former species. It is the purpose of the writer to give only a brief resume of the more important literature on each species, in so far as it bears on the subject under discussion in this paper.

*Collybia velutipes*, commonly called the "velvety-stemmed Collybia," may be recognized readily by its yellow-brown pileus, which is viscid when moist; its stipe, which is dark brown and velvety at the base; and its habit of growing in more or less densely crowded clusters, both as a saprophyte on dead wood and as a wound-parasite on the roots and exposed wounds in living dicotyledonous trees, particularly species of *Ulmus*. It is unusual among the Agaricaceae in the early appearance of its sporophores, it being one of the few agarics that persist throughout the winter uninjured by freezing.

Biffen (1), who gives the most comprehensive account of the biology of this fungus, describes in detail the decay of the wood based on sections of culture blocks of horse-chestnut wood. According to him, *Collybia velutipes* attacks chiefly the cellulose portions of the wood elements, leaving a lignin skeleton. He concludes that soluble carbohydrates are of great importance in the proper nutriment of the fungus but that, in their absence, it is capable of varying its usual course of action and using lignin as a substitute. For example, when the wooden culture blocks, prior to their inoculation, were treated with caustic potash, which extracts the xylose-yielding substances, the sections cut from the wood, after its decay by the fungus, give a cellulose reaction with chloroiodide of zinc. In these sections Biffen found that the thickening layers stained a deep purple and were swollen so as to almost obliterate the lumen, the microchemical reaction being the same as given by wood infected by typical lignin-destroying fungi. He found that similarly extracted, but uninfected, wood gave no such reaction. He found, however, that if wood from which the xyloses had been removed be treated with a 1 per cent solution of cane sugar before infection, the action of the mycelium was similar to that in wood in which its chemical structure had not been artificially altered, that is, that the lignin was left unattacked.

*Pleurotus ostreatus*, commonly called the "oyster mushroom," usually occurs saprophytically but has been noted by various writers as a wound parasite on living trees, particularly shade trees. Its large, whitish to

dark gray, fruiting bodies are greatly esteemed by those who know their edible qualities—in fact, the lupine-covered sand dunes at Fort Scott, San Francisco, are frequently visited by one or more parties who are cognizant of the edibility of this fungus.

Learn (8), who gives the most comprehensive account of the biology of this species, describes in detail the decay of sugar maple (*Acer saccharum*) wood by this fungus. According to Learn, the results obtained for cellulose tests indicate that there is a gradual delignification of the cell-wall proceeding from the lumen outwards. As the cell-wall becomes delignified the lumen increases in size, the middle lamella being the last to be delignified in the advanced stages of the rot; in the very last stages of the decay even the middle lamellae may be broken down.

Learn found that the early wood of the annual ring became delignified much more rapidly than the late wood and that the medullary rays, which, in sugar maple wood, are several cells broad and strongly lignified, persist longer than the remaining elements. In addition he demonstrated the presence of diastase in the mycelium of the sporophore and made tests on ground rotten wood for hadromal, according to the methods employed by Czapek. From these he concluded that the hadromal is not entirely removed, while if there is a reduction of the hadromal it must be in very small quantities. The tests showed that the hadromal was still left behind in considerable quantities in the cell walls.

STRUCTURE OF THE NORMAL WOOD OF LUPINUS ARBOREUS

The wood of *Lupinus arboreus* is of extremely rapid growth, hard and close-grained, whitish, with heartwood absent, and possesses but little durability. When freshly cut it has a rather disagreeable leguminous odor.

Macroscopically the wood is of the ring-porous type, with exceptionally broad and rather indistinct growth rings, and inconspicuous pores. The pores, which lack tyloses, occur in more or less regular tangential lines and tend to become somewhat more numerous but not much larger in the early wood. On the ends of stems trimmed with a very sharp knife or razor the growth rings are demarked by what appears to be a more or less prominent tangential row of radially elongated vessels in the beginning of the annual ring. In seasoning this is accentuated by a slight honeycombing of the wood at this point. The medullary rays are very broad and conspicuous.

Microscopically there is no sharp line of demarcation between the different layers of growth. What appeared under the hand lens to be a row of radially elongated vessels proves to be the very thin-walled, hyalin medullary rays, which, particularly in the outer portion of the last growth

ring (in stems cut December 26), and to a lesser degree at the extreme periphery of each preceding one, consist of very thin-walled, hyaline cells entirely devoid of any layers of secondary thickening and of the numerous simple pits characteristic of the normally thickened ray cells. The growth rings are seen to be defined principally by the unlignified ray cells at their extreme periphery, and the gradual diminution of the vessels throughout the ring, both in size and numbers, which results in a slightly greater density of the late wood. Under the microscope the wood is seen to consist of the following elements: (a) multiseriate pith-rays, (b) comparatively small vessels, (c) wood fibers, (d) tracheids, and (e) wood-parenchyma fibers (Plate XX, A).

The multiseriate pith-rays are mostly 6–10 cells wide, high, conspicuous, and regularly disposed; the largest rays are as broad as the largest pores and their cells are homogeneous.

The comparatively small vessels occur singly or as more or less radial groups of from 2–4, disposed in irregular wavy lines. The individual vessels are composed of numerous relatively thin-walled, short tube-like segments arranged horizontally end to end, with more or less oblique end walls, particularly in the smaller ones. The sides in contact with other vessels are usually much flattened and bear numerous small bordered pits.

The wood fibers form the ground mass of the wood between the wide rays and occur in more or less compact masses alternating with more or less irregular, wavy lines of vessels. They can be distinguished readily from the other elements in transverse sections, microscopically, by their much thicker walls and, microchemically, by the lack of lignification in the laminae of thickening bordering on the lumen.

The tracheids are found adjacent to the vessels, together with the wood-parenchyma fibers. In transverse sections these elements can be distinguished readily from the wood parenchyma fibers by their much thinner walls.

### MICROCHEMICAL TESTS OF SOUND WOOD OF LUPINUS ARBOREUS

As a preliminary to the detailed study of the decays by the two fungi here under consideration a series of microchemical tests with the most commonly used reagents was performed on sections of the sound wood of *Lupinus arboreus*, since it is believed that a knowledge of the relative cellulose and lignin content of the cell membranes, in conjunction with their anatomical features, will facilitate a clearer conception of the specific way in which the decay of the wood is brought about by the mycelium of these fungi.

The writer has refrained from giving in detail the specific reactions of the cell walls to the various reagents employed for the detection of lignin and cellulose, since they offer nothing fundamentally new.

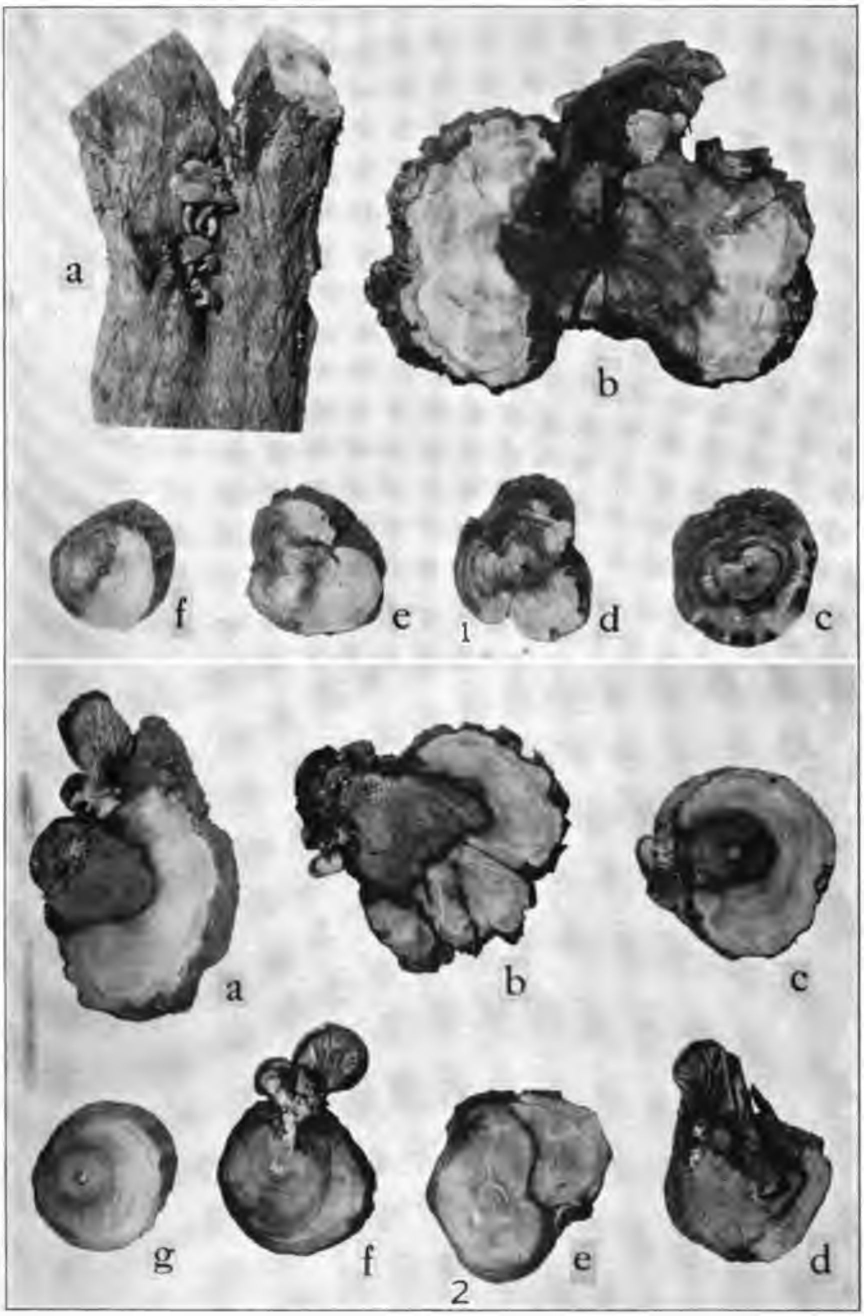
All the microchemical tests used agree with one another, not only in their differentiation of the cellulosic and lignified membranes, but also in the degree of lignification exhibited by the different wood elements. The results of these tests indicate that the unthickened middle lamella of the younger medullary ray cells and the laminae of thickening bordering on the lumina in all the wood fibers consist largely of cellulose and that the entire walls of the vessels, normally thickened medullary ray cells, tracheids, wood-parenchyma fibers, and middle lamellae and secondary laminae of thickening in the wood fibers are strongly lignified. Of the wood elements whose membranes are lignified, the vessels and medullary ray cells are by far the most strongly lignified, the vessels appearing a trifle more so than the ray cells. The remaining elements, namely the tracheids, wood-parenchyma fibers, and middle lamellae and secondary laminae of thickening in the wood fibers appear to be lignified to approximately the same extent.

### THE DECAY OF LUPINUS ARBOREUS STEMS BY COLLYBIA VELUTIPES AND PLEUROTUS OSTREATUS

The course of the decay of *Lupinus arboreus* stems by *Collybia velutipes* and that by *Pleurotus ostreatus* were each worked out in full detail, using large numbers of microtome sections of the wood in all stages of the decay. The decays of lupine wood by these respective fungi were found to be practically identical in their character, differing only in the late stages of the rot in that the decay caused by *Pleurotus ostreatus* progresses somewhat farther than that caused by *Collybia velutipes*. For the sake of brevity, therefore, but the one description will be given in which the few points of difference between the two decays will be pointed out specifically.

The first evidence of decay in the living stem is the occurrence of a slight brown discoloration, usually irregular in outline and very striking against the background of white sapwood. This brown discoloration invariably starts at some dead branch stub, insect tunnel, split crotch or other mechanical injury, and from this point spreads up and down the stem as it gradually develops into the typical rot.

The decay spreads up and down the stems much faster than it does across them. It may start somewhere near the center of the stem and work outward until the periphery is reached, or it may start on one side of the stem (Plate XIX, figs. 1 and 2), killing this side as it extends up and down, and gradually extending across the stem until the whole of it is decayed. In the latter case one or more growth rings may be formed partially around the stem before the whole of it, as seen in cross section, becomes rotted by the advancing fungus.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When infection, by either of these fungi, occurs in a lateral branch the decay invariably is transmitted to the main stem. When infection occurs near the base of the stem the rot invariably is ultimately transmitted to the other stems of the bush, in case it has more than one stem.

Sections taken through the brown discolored wood, which, as stated previously, represents the first stage of the decay, show no perceptible change in either the physical or chemical structure of the wood itself. A microscopic examination of such sections shows the presence of mycelium occurring more or less abundantly in the vessels and some of the adjoining elements, but not of general occurrence throughout the wood; also that the enzymatic activity of the fungus is evident since the wood elements containing the hyphae are usually full of a brownish black decomposition product. This substance, as stated by the writer (10 and 11), is regarded as a humic by-product of the decay in the wood and usually starts as a result of the transformation of the cell contents by the action of the mycelium before the dissolution of the walls of the wood elements has begun. Evidence of the latter is offered by the result of microchemical tests made on sections of the brown discolored wood. The standard microchemical tests employed for the recognition of cellulosic membranes, as well as those commonly employed for the recognition of lignified membranes, all agreed in demonstrating that the wood in this incipient stage of the decay behaves exactly as does the normal wood.

Following along the longitudinal section of the diseased stem, often but a very short distance, the brown discolored wood is seen to gradually merge into the typical, lighter brown rot. Sections of wood cut through this transition point in the decay show that the brown decomposition products usually tend to become so abundant as to form a zone of varying width and regularity between the decayed and the undecayed wood. Under the microscope it is seen that the brownish black decomposition products become so abundant as to more or less completely fill the lumina of all the wood elements. This zone of brownish black decomposition products which delimits the decayed from the undecayed wood always keeps pace with the progress of the decay. These by-products of the decomposition apparently are more or less completely destroyed by the mycelium while new ones are formed immediately in advance of the hyphae invading the living wood.

Just behind the advancing zone of brownish black decomposition products, which roughly marks the limits of the advancing mycelium, can be seen the first stage in the dissolution of the cell walls. The first evidence of this occurs in certain of the wood fibers where it is noted that the tertiary laminae of thickening (the cellulosic laminae bordering on the cell lumen) in these elements gradually diminish in thickness until, but a very short distance back of the dark brown zone bounding the de-

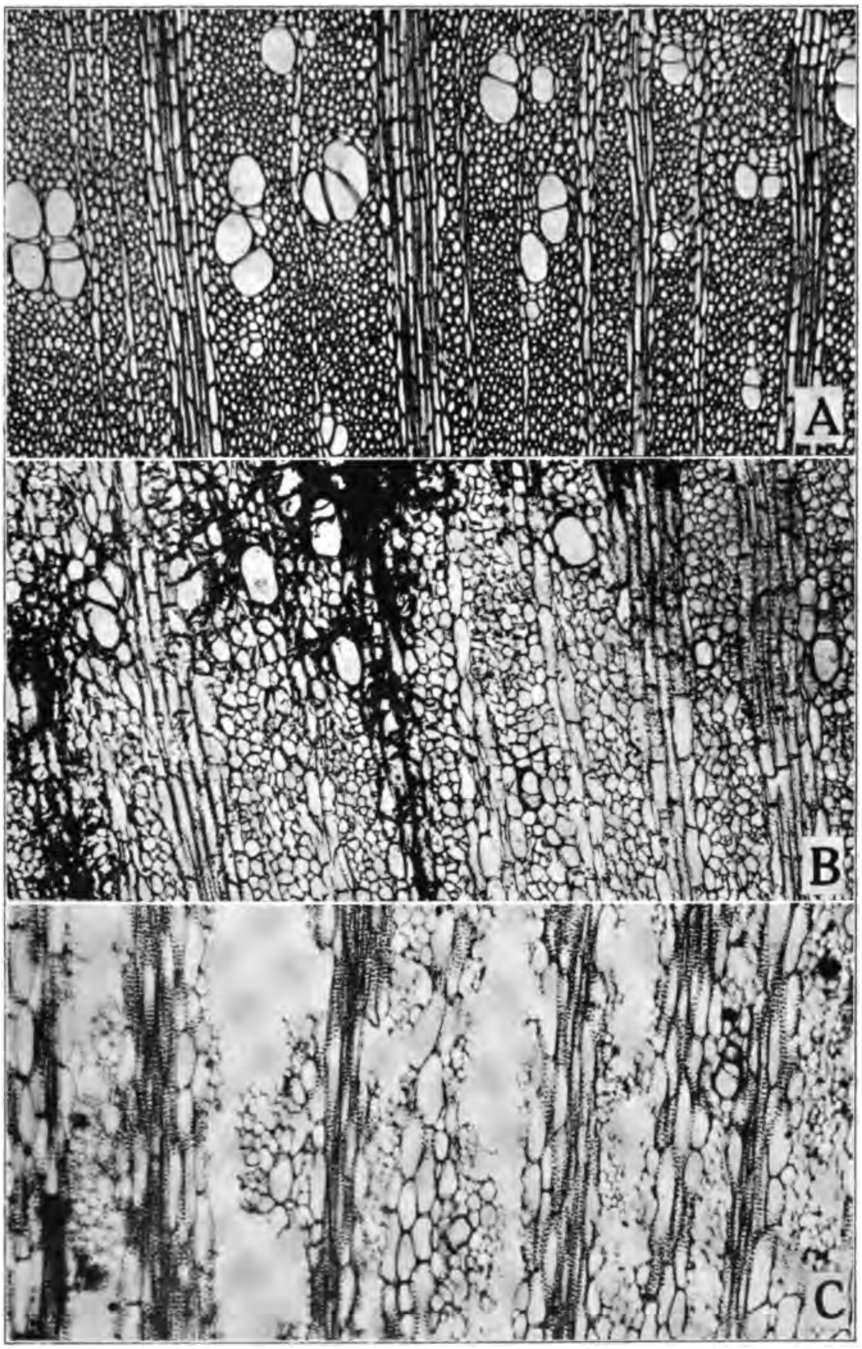
cayed area, this layer is seen to be dissolved completely in practically all the wood fibers. A repetition of the microchemical tests previously made on sound wood for the detection of lignin showed that the middle lamellae and secondary laminae of thickening in the wood fibers, together with the entire walls of the other elements, still respond as strongly as they did in the tests made on sound wood. Microchemical tests for cellulose, however, gave positive results only where the cellulosic layers, bordering the lumina of the wood fibers, still remained intact.

As the decay progresses the rot column enlarges, both longitudinally and in transverse area. As a rule, however, it is always characterized by the dark brown zone of decomposition products between its periphery and the adjoining sound wood.

Proceeding still farther back from the margin of the decayed wood, it is evident that the secondary layers of thickening in the wood fibers, tracheids, and wood parenchyma fibers are becoming dissolved progressively until, but a short distance farther, only the middle lamellae of these elements remain (Plate XX, A, B). At this point in the decay of the wood many of the wood elements between the medullary rays, with the exception of the vessels, have a skeletonized appearance. The middle lamellae of the dissolved cell walls retain the nature of lignified membranes and prove quite resistant to decay, but ultimately become so thin that, in parts of the sections, they were found to be broken up into dissociated fragments, probably under the stress of sectioning. At this stage of the decay the vessels and ray cells still respond to microchemical tests for lignin almost as strongly as they did in the sound wood. These elements, which originally were strongly lignified, appear to remain almost intact until the intervening wood elements are practically entirely skeletonized.

By the time the decay has progressed to this stage the rot usually extends completely out to the bark in case it started at the center of the stem, or, in case it started at one side of the stem, the majority of the living wood, as shown in cross section, has become well decayed. Stems rotted at or below the ground level usually can be broken off with comparatively little effort, even before the decay has progressed this far, providing that the decay has extended clear across the stem. With the completion of the decay in the stem the black zone, formerly appearing in advance of the rot column, is usually found to have disappeared from the stem.

*Lupinus arboreus* wood decayed by *Collybia velutipes* rarely becomes soft and pith-like as does that decayed by *Pleurotus ostreatus*, and then only in small localized areas where the decay, for some reason or other, progresses beyond the average for the whole stem. Whole stems never become soft and pith-like and white as do those decayed by *Pleurotus*


A
B
C

*ostreatus*. In the decay caused by *Collybia velutipes* the delignification of the wood elements usually does not progress to the same extent as in that caused by *Pleurotus ostreatus* and the decay seems to have run its course long before the wood substance is thoroughly destroyed.

In the decay caused by *Collybia velutipes* the wood elements, as a whole, do not become dissolved down to their middle lamellae, as readily, or at least not as quickly, as in the rot caused by *Pleurotus ostreatus*. In the former species the decay usually develops entirely across the stem before the wood elements are seriously broken down. Dead stems bearing clusters of sporophores at their bases, as a rule, can be broken off transversely with comparatively little physical effort. However, the yellowish-brown decayed wood is still found to be fairly hard. A microscopic examination of the wood at this stage of the decay shows that the majority of the wood elements are rarely dissolved down to their middle lamellae but still retain much of their secondary laminae. It also frequently happens that a portion of the brown by-products of decomposition is left behind in the decayed wood, particularly in the lumina of the vessels and adjoining elements (Plate XX, B). They are so scattered, however, as to be evident only when the section is examined under the microscope.

In decayed roots dug out of the sandy soil, where the maximum amount of decay is to be expected, the late stages of decay are to be found. At this stage the decayed wood is soft and spongy and brownish white in color. The annual rings of growth often separate readily and the wood can be broken readily in all directions, between the fingers. When dry it is light in weight and very punky; it can then be crumbled between the fingers to a fine powder.

By the time the wood has reached the advanced stage of decay just described, it invariably is discolored. It is reasonably certain that in lupine wood decayed by *Collybia velutipes*, continued destruction beyond this point is largely the work of other agencies. After a stem becomes rotted clear through and its death ensues, it is but a short time until the partially decayed wood is tunnelled into by ants and other insects.

In the decay caused by *Pleurotus ostreatus*, as soon as the decay progresses beyond the initial dark brown discoloration, the wood becomes yellowish brown in color. In the extreme stages of the decay the wood tends to become white and pith-like. The pith sometimes is replaced by a solid core of white mycelium and small white mats of mycelium frequently develop in the clefts formed in the decayed wood (Plate XIX, fig. 2, e), an occurrence never noted in the rot caused by *Collybia velutipes*. As in lupine wood decayed by *Collybia velutipes*, however, brown by-products of the decomposition are occasionally left behind in the decayed wood, particularly in the lumina of the vessels and the adjoining elements, although they are not to be found in any appreciable quantity.

When these late stages of the decay are reached the dissolution of the ray cells and vessels begins (Plate XX, C). At this stage of the decay the fine, colorless mycelium is seen to have spread throughout the wood substance, the individual hyphae penetrating the cells in all directions. By this time the wood is whitish and pith-like, tending to break readily both transversely and longitudinally. When wet it can be compressed at right angles to the pith rays by slight pressure between the fingers, since all the wood elements between the rays have become skeletonized, and the water quickly runs out of it; as soon as the pressure is released the water is instantly absorbed, as in a sponge. The decayed wood is most resistant to radial compression, under which it tends to break up into a series of radial sheets—the medullary rays—which resist decomposition longer than the wood fibers which form the ground work of the wood. After the pith-like decayed wood has become dry it becomes much more resistant to radial compression, under which the rays crumple, much as a deck of cards will do when compressed with sufficient strength. When dry, wood in this stage of the decay can be reduced to a flaky powder by rubbing between the fingers.

From the above study it is evident that the first main chemical change brought about by the action of the mycelium, in the case of both fungi under discussion, is the dissolution of the cellulosic layer bordering on the lumina of the wood fibers. The dissolution of this layer starts at the lumen and progresses toward the middle lamella. After the available cellulose has been digested the dissolution of the lignified membranes remaining occurs in the same way, beginning first with the ones least lignified. In this dissolution of the lignified membranes no free cellulose could be detected at any time during the course of either decay, although in the decay of *Acer saccharum* wood by *Pleurotus ostreatus*, Learn (8) states that "the reduction of the lignified tissue to cellulose is a very slow process."

The course of the destruction of *Lupinus arboreus* wood by *Collybia velutipes* agrees essentially, in so far as the salient features are concerned, with that described by Biffen (1) for horsechestnut wood; the course of the destruction of *Lupinus arboreus* wood by *Pleurotus ostreatus* likewise agrees essentially with that described by Learn (8) for *Acer saccharum* wood.

## SUMMARY

*Collybia velutipes* and *Pleurotus ostreatus* are reported as serious wound-parasites on *Lupinus arboreus*, causing widespread destruction of this arborescent shrub which grows naturally on sand dune land in the vicinity of San Francisco, where it is of considerable economic importance as a soil retainer. In one case *Armillaria mellea* was also found attacking *Lupinus arboreus*. Occasionally *Collybia velutipes* also is a wound parasite on *Lupinus chamissonis*. These two species of lupine are here reported for the first time as hosts for these fungi.

Infection of *Lupinus arboreus* stems by these fungi is largely due to tunnels made in the stems by the larvae of the moth, *Hepialus sequoiolus*, and to such mechanical injuries as split crotches, which are of frequent occurrence, and to dead branch stubs.

As the result of a reconnaissance of a portion of one area of dune land covered by *Lupinus arboreus* growth it was found that, out of a total of 541 living bushes, 156, or 29 per cent, exhibited sporophores of wood-rotting fungi, as follows: 130, or 24 per cent, with *Collybia velutipes*; 25, or 5 per cent, with *Pleurotus ostreatus*, and 1 with *Armillaria mellea*. On this same sample plot 84 dead bushes were found. Of these, 26, or 31 per cent, exhibited sporophores of *Collybia velutipes* and 5, or 6 per cent, exhibited sporophores of *Pleurotus ostreatus*. Most of the remaining 53 dead bushes exhibited more or less decay, many of them being completely rotted. The production of the sporophores of these fungi was in direct relation to the amount of precipitation.

The decays of *Lupinus arboreus* wood by *Collybia velutipes* and *Pleurotus ostreatus* were found to be practically identical in character, differing only in the late stages of the rot in that the decay produced by *Pleurotus ostreatus* progresses somewhat farther and causes the wood to become whiter than that produced by *Collybia velutipes*. The first main chemical change brought about by the action of the mycelium in the case of both fungi is the dissolution of the cellulosic layers bordering on the lumina of the wood fibers. The dissolution of this layer starts at the lumen and progresses toward the middle lamella. After the available cellulose has been digested the dissolution of the lignified membranes remaining occurs in the same way, beginning with the ones least lignified.

By reason of its greater longevity, its tougher wood and more compact form, both of which qualities retard the splitting of the branch crotches, and its freedom from attacks by boring insects, *Lupinus chamissoni*, will be found decidedly preferable to the associated species, *L. arboreuss* for a permanent sand dune cover.

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### PLATE XVIII

Fig. 1. Occurrence of *Collybia velutipes* on living shrub of *Lupinus arboreus*, showing a cluster of sporophores that have developed from the junction point of two stems below the ground line and a cluster that have developed out of a wound on the stem at the right.

Fig. 2. Occurrence of *Pleurotus ostreatus* on a dead shrub of *Lupinus arboreus*, showing abundant young sporophores developed from the common base of the stems.

### PLATE XIX

Fig. 1. Sections of living stems of *Lupinus arboreus* attacked by *Collybia velutipes*: *a*, sporophores developing out of split crotch; *b*, section just below another split crotch,

showing sporophore and rot; *c, d, e,* and *f,* sections showing rot in living stem at ground line and at points one, two, and three inches above the ground-line. × ½ natural size.

Fig. 2. Sections of living stems of *Lupinus arboreus* attacked by *Pleurotus ostreatus:* *a,* section just below forks with dead rotten branch, showing sporophore and progress of rot down main stem, resulting in the early death of one side; *b,* section of same stem at point three inches below *a,* showing small sporophore at one side of dead wood; *c,* section of same stem 11 inches below *b,* showing small sporophore at one side of dead wood; *d,* section through another infected stem at point of emergence of dead branch stub, showing sporophore developed out between bark and wood; *e,* section through still another infected stem, taken just below fork in stem, and showing the complete decay of branch on left side with pith replaced by a core of mycelium, and spread of decay into the branch on right side; *f,* section of same stem at point one inch below *e,* showing sporophores growing out of rotten stub; *g,* section of same stem at point four inches below *f,* showing initial stages of the decay. × ½ natural size.

## PLATE XX

A. Transverse section of normal wood of *Lupinus arboreus,* showing the character of the wood elements. × 68.

B. Transverse section of *Lupinus arboreus* wood decayed by *Collybia velutipes,* showing the dissolution of the secondary layers of thickening in the wood elements, and the dark brown decomposition products left in the wood. × 68.

C. Transverse section of *Lupinus arboreus* wood decayed by *Pleurotus ostreatus,* showing the dissolution of the secondary layers of thickening in the wood elements. × 68.

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# RESISTANCE OF BARLEY TO HELMINTHOSPORIUM SATIVUM P. K. B.

H. K. Hayes and E. C. Stakman[1]

The spot blotch disease of barley has been known in the United States for about ten years. In 1910 Pammel, King, and Bakke described a new spot disease of barley caused by *Helminthosporicm sativum*. n. sp. Attention was called to the seriousness of the disease, and preliminary observations were made on varietal resistance. Later Johnson did considerable work on the disease and suggested (1913), as the common name, American blotch disease. Recently it has been called the spot blotch disease of barley.

It has been known for several years that the spot blotch disease is quite important in Minnesota. Since repeated infections may occur during the growing season, seed treatment will not eliminate the disease. It has been known for some time that the causal organism can attack wheat as well as barley. Recent work (Stakman, 1920) seems to indicate that *H. sativum*, or a form practically indistinguishable from it, commonly causes foot rot of wheat and rye in Minnesota and is capable also of infecting several wild grasses. Obviously, therefore, crop rotation and sanitation will not control the disease entirely.

Manchuria barley, which is the predominant variety in the Upper Mississippi Valley, is fairly resistant to the spot blotch disease. However, the long, rough awns make the barley crop very unpopular with the farmer. Hooded barleys are much easier to handle but do not yield well in humid regions. Furthermore, Harlan and Anthony (1920) have shown that the barley awn is an important physiological organ. The importance of smooth-awned barley was therefore recognized several years ago by Harlan, of the Office of Cereal Investigations, who recently (1920) described some importations of *Hordeum vulgare nigrum leiorrhynchum*, smooth-awned barleys. Lion, one of these smooth-awned barleys, was crossed with Manchuria with the hope of producing high-yielding, smooth-awned barleys suitable for Minnesota conditions. Harlan and Hayes (1919), in co-operative experiments between the Department of Agriculture of the University of Minnesota and the Office of Cereal Investigations of the United States Department of Agriculture, made an intensive study of several smooth-awned strains from crosses between Manchuria and Lion in comparison with high-yielding, rough-awned varieties. Three of these smooth-awned selections yielded well in the

[1] Published with the approval of the Director as paper 251 of the Journal series of the Minnesota Agricultural Experiment Station.

rod row nurseries at the Minnesota Experiment Station and at the substations, from 1916 to 1918 inclusive. In subsequent years, however, they have not yielded well. Very evidently this was largely due to the fact that they are susceptible to *H. sativum.* It was quite clear from casual observations that resistance or susceptibility to the spot blotch disease was an important factor in causing differences in yield between various strains and crosses of barley. For this reason a more careful study of varietal resistance has been made. Studies also are being made on the resistance of crosses between the rough-awned barleys and the smooth awned types.

Although the results presented are preliminary, the facts show quite clearly that barley varieties differ greatly with respect to susceptibility to *H. sativum.* It also has been shown that resistance and susceptibility are inherited, although the actual number and nature of inherited factors is not known.

TABLE I

*Correlation in barley between yield in bushels obtained from replicated rod row test and reaction to H. sativum. University Farm, 1920*

| Yield in bushels per acre | Reaction classes to H. sativum | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | L | L+ | M— | M | M+ | H— | H | H+ | |
| 15 | | | | | | | | 1 | 1 |
| 27 | 1 | | | | | | | | 1 |
| 30 | 1 | | | | | | 1 | 2 | 4 |
| 33 | | | 1 | | 1 | 1 | | | 3 |
| 36 | | | 1 | 1 | 2 | | 1 | | 5 |
| 39 | 1 | 1 | | 1 | 1 | | | | 4 |
| 42 | 3 | 2 | | 1 | | | 4 | | 10 |
| 45 | | 4 | 1 | 1 | | | | | 6 |
| 48 | 2 | | | 2 | | | | | 4 |
| 51 | | 2 | | | | | | | 2 |
| 54 | | | | 1 | | 1 | | | 2 |
| 57 | 2 | | | | | | | | 2 |
| 66 | | | | | 1 | | | | 1 |
| | 10 | 9 | 3 | 7 | 5 | 2 | 6 | 3 | 45 |

$r = -.36 \pm .09$

### THE RELATION BETWEEN YIELD AND RESISTANCE

Varieties and crosses of barleys were studied both under natural conditions and after being subjected to an artificially induced epidemic of the spot blotch disease. A considerable number of commerical varieties and purified smooth-awned crosses were grown in five-foot rows in the Plant Pathology Nursery. An epidemic was induced in 1920 by spraying the plants repeatedly with a suspension of spores from pure cultures of *H. sativum.*

Data also were taken on the resistance of varieties grown in rod rows in the Plant Breeding Nursery in which only a natural epidemic developed. Three rows of each variety were grown in each of three different plots, systematically distributed over this nursery. The yields of the central row of each plot were determined and these were averaged for each variety.

TABLE 2

*Correlation between manner of reaction of 45 barley varieties to H. sativum under artificially produced epidemic conditions in the plant pathology plots and the manner of reaction in the plant breeding nursery. 1920*

| Manner of reaction, plant breeding nursery | Manner of reaction, plant pathology plots: T+ | L— | L | L+ | M— | M | M+ | H— | H | H+ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T+ | | | | | | | 1 | | | | 1 |
| L | | | 4 | 1 | 3 | 2 | | | | | 10 |
| L+ | 3 | 2 | 2 | 1 | 2 | | | | | | 10 |
| M— | | | | | | | | 1 | | | 1 |
| M | | | 3 | 1 | 2 | 1 | 2 | | | | 9 |
| M+ | | | | 2 | | 3 | | | | | 5 |
| H— | | | | | 1 | | | | | | 1 |
| H | | | | | 1 | 2 | 1 | 1 | | 1 | 6 |
| H+ | | | | | 1 | | | | 1 | 1 | 2 |
| | 3 | 2 | 9 | 5 | 10 | 8 | 4 | 2 | 1 | 2 | 45 |

$r = .49 \pm .08$

The severity of attack by *H. sativum* was denoted by the following words: trace, light, medium, and heavy. Plus and minus signs were used to indicate plus or minus variations within each respective class. No variety was entirely immune to the spot blotch disease, but there were sharp differences in the susceptibility of different varieties and crosses. All of the strains were selections or crosses which, on the basis of previous tests, seemed to be promising under Minnesota conditions.

A correlation coefficient was computed between the manner of reaction to *H. sativum* and the average yield of the varieties and crosses. (See table 1.) While only forty-five forms were used in the test, the use of the correlation table is justified, since it presents clearly and concisely the extent of the apparent relation between susceptibility or resistance to Helminthosporium and the yield in bushels per acre. The computed correlation coefficient was $-.36 \pm .09$. This shows that in general the resistant varieties yielded best. Yield may be considered the end result of the interaction of numerous inherited or environmental factors, among which disease resistance is one.

Some varieties and strains were grown both in the Plant Pathology Nursery and in the Plant Breeding Nursery. The reaction of these plants to *H. sativum* is shown in correlated form in table 2. Some of these varieties are the same as some of those for which which data are given in table 1.

The degree of infection of the different varieties in the two nurseries was approximately comparable. However, the correlation coefficient. .49 ± .08 is not especially high. No sharp line of differentiation between the different classes of infection could be drawn. The various types of infection formed a closely intergrading series. Those varieties, however, which were slightly infected in one nursery were infected in a somewhat similar manner in the other nursery and vice versa. This indicates that the difference between classes is genetic.

TABLE 3

*Correlation between average manner of reaction to H. sativum in 1920 and yield under replicated rod row test in 1919*

| Yield in bushels per acre, 1919 | Reaction classes to H. sativum: L | L+ | M− | M | M+ | H− | H | H+ | |
|---|---|---|---|---|---|---|---|---|---|
| 18 | | | | 1 | | 1 | | 1 | 3 |
| 21 | | | 1 | | 1 | | | | 2 |
| 24 | | | 1 | | | 1 | | | 2 |
| 27 | | | | | | 2 | | 1 | 3 |
| 30 | | | | | | | 1 | | 1 |
| 33 | | | | | | | 1 | | 1 |
| 36 | 1 | 1 | 1 | | | | | | 3 |
| 39 | | | | 1 | | | | | 1 |
| | 1 | 1 | 3 | 2 | 1 | 4 | 2 | 2 | 16 |

$r = -.38 \pm .14$

No data were taken on the degree of infection in the rod row plots in the Plant Breeding Nursery in 1919, although many varieties were heavily infected. Some varieties which were grown in the Plant Breeding Nursery in 1919 also were grown in 1920 and data were taken on their susceptibility to *H. sativum*. Sixteen varieties were grown both in the Plant Breeding Nursery and in the Plant Pathology Nursery in 1920. The reaction of these varieties to *H. sativum* in the two tests was averaged and this result was correlated with the results of the yield tests in the replicated rod rows in 1919. (See table 3.) It is evident from the table that the varieties which were resistant in 1919 in general yielded more than the susceptible varieties.

### COMBINATION OF RESISTANCE TO H. SATIVUM AND THE SMOOTH-AWNED CHARACTER IN A SINGLE VARIETY.

Since no entirely satisfactory smooth-awned variety was obtained from the first series of purified crosses, more crosses were made between smooth-awned barley and various six-rowed forms. These crosses were made by Dr. H. V. Harlan of the Office of Cereal Investigations, United States Department of Agriculture, at Aberdeen, Idaho, in 1917. The parental forms were pure lines, and the $F_1$ crosses were grown in the greenhouse of the United States Department of Agriculture at Washington in the winter of 1917 and 1918. The subsequent study, from $F_2$ to $F_4$ inclusive, was made at the Minnesota Experiment Station. Fifty plants of several $F_3$ familes were grown in 1919. All of these familes were grown from smooth-awned plants selected in 1918, and they bred true for the smooth-awned habit. The awns of some of the plants, however, are smoother than those of other plants. All of the smooth-awned plants have a few sharp projections at the base of the awn and on the upper third. These projections, however, are much shorter than those on the tooth-awned varieties.

TABLE 4

*Manner of reaction under artificial epidemic conditions of smooth and tooth awned barley parents and sixteen $F_4$ families to Helminthosporium sativum*

| Parents and $F_4$ Purified crosses | Reaction classes | | | | | | |
|---|---|---|---|---|---|---|---|
| | L | L+ | M− | M | M+ | H− | H |
| Tooth-awned parents............ | 3 | 4 | | | | | |
| Smooth-awned parents.......... | | | | | | 1 | 2 |
| $F_4$ families...................... | 2 | 2 | 3 | 3 | 3 | 1 | |

There was a very clear difference in the resistance of the different $F_3$ families to *H. sativum*. The plants in some of the families were extremely susceptible. Those of others were resistant, and in some of the families some plants were resistant while others were susceptible. The plants of some of the $F_3$ families apparently were uniform for general agronomic and botanical characters and also were resistant to *H. sativum*. The smooth-awned, pure line parents of these crosses were highly susceptible in 1920 both in the Plant Pathology Nursery and in the Plant Breeding Nursery. The rough-awned parents, on the other hand, were highly resistant.

Seventeen $F_4$ families were grown in the pathology plots. Sixteen of these appeared to be homozygous in their manner of reaction to *H. sativum*. These families had been selected in the $F_3$ because they seemed to be desirable types. The reaction of these sixteen $F_4$ families and the

reaction of their parents are given in table 4. It is evident from these results that resistance and susceptibility to *H. sativum* segregate in barley crosses between resistant and susceptible parents. The results show also that, by crossing, a variety may be obtained combining the resistance of the rough-awned parents with the smooth-awned character of the smooth-awned parents.

## RESISTANCE OF COMMERCIAL BARLEY VARIETIES

A preliminary study was made of the relative resistance of commercial varieties of barley. The results are given in table 5.

TABLE 5

*Comparative resistance of commercial barley varieties to Helminthosporium sativum*

| Species[1] and Variety | Commercial Variety | Degree of Infection |
|---|---|---|
| Hordeum vulgare pallidum | Manchuria | |
| | Pure line 1 | M |
| | Pure line 2 | M— |
| | Pure lines 3 and 4 | L+ |
| | Pure lines 5–10 inc. | L |
| Do | Servian | H |
| Do | Trebi | M+ |
| Do | Odessa | H— |
| Do | Bay Brewing | H |
| Do | Tennessee Winter | L |
| Do | Winter Club | M— |
| Do | Mariout | H+ |
| Hordeum vulgare nigrum | Gatami | L |
| Hordeum vulgare horsfordianum | Horsford Beardless | M+ |
| Hordeum vulgare coeleste | Himalaya | M+ |
| Do | Black Hull-less | H— |
| Do | Nepal x Manchuria | |
| | (Several purified crosses) | L |
| Hordeum vulgare trifurcatum | Nepal | L |
| Hordeum distichon palmella | Hanna | L |
| Do | Chevalier | L |
| Do | Hannchen | L |
| Do | Svanhals | L |

[1]The classification proposed by Harlan has been used.

## SUMMARY

1. During the progress of breeding work, undertaken for the purpose of producing smooth-awned barleys, the importance of resistance to the spot blotch disease, caused by *Helminthosporium sativum*, became very apparent.

2. Crosses were made between Lion, a smooth-awned variety susceptible to *H. sativum*, and Manchuria, a rough-awned, resistant variety.

3.The first group of homozygous crosses which were increased and tested did not yield well. This apparently was due to the fact that these crosses were as susceptible to *H. sativum* as is Lion, the smooth-awned parent.

4. After the failure of the first group of crosses, further crosses were made between Manchuria and Lion. A considerable number of the resulting $F_3$ smooth-awned families were grown in 1919, and a fairly severe epidemic of the spot blotch disease developed. Some $F_3$ families were as resistant as the Manchuria parent; others were as susceptible as the Lion parent; and in some of the families both resistant and susceptible plants appeared.

5. Some $F_3$ families were selected in 1919 and were tested carefully in 1920. Some families were obtained which combined desirable botanical and agronomic characters, including smooth-awns, with resistance to *H. sativum.*

6. A preliminary study was made in 1920 of the resistance and susceptibility of commercial varieties of barley. From the results obtained it seems reasonable to conclude that resistant barleys of any desired botanical group of Hordeum can be produced.

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# VIOLET ROOT ROT (RHIZOCTONIA CROCORUM DC.) IN THE UNITED STATES

JAMES A. FARIS[1]

## INTRODUCTION

During the fall of 1919 specimens of potatoes covered with a violet felt of mycelium were received by the Department of Pathology of the University of Nebraska. These diseased tubers came from Sheridan County where the growers reported having observed the disease over a period of three years. Further investigations showed the disease present on potatoes in Kimball and Cherry Counties in the same state. The experimental plots at Gordon, Nebraska, were heavily infected, even though the seed tubers had been treated for black scurf (*Rhizoctonia solani* Kühn) with mercuric bichloride solution (1–1000).

During the growing season of 1920 the writer made numerous observations of plants infected with *Rhizoctonia crocorum* DC. Through this entire season the disease was very prevalent in the potato growing region of northwestern Nebraska.

## PREVIOUS REPORTS OF VIOLET ROOT ROT IN THE UNITED STATES

The following table shows a steady increase in the known range of this fungus throughout the United States:

TABLE 1

*Violet root rot in the United States*

| YEAR | HOST | AUTHOR | STATE |
|---|---|---|---|
| 1915 | Solanum tuberosum | Bailey (3) | Oregon |
| " | " " | Rees (16) | Washington |
| 1916 | " " | Heald (13) | " |
| 1889 | Medicago sativa | Pound (17) | Nebraska |
| 1900 | " " | Tyler (21) | Arizona |
| 1906 | " " | Heald (11) | Nebraska |
| 1908 | " " | Freeman (9) | Kansas |
| 1913–1914 | " " | Reed & Crabill (19) | Virginia |
| 1914 to 1919 | " " | Johnson & Haskell (14) | Iowa, Kansas & Nebraska |
| 1915 | " " | Arthur (14)<br>Jackson (14) | Indiana |
| 1916 | " " | Diehl (5) | Iowa |

[1] The author is indebted to the University of Nebraska for the use of their pathological laboratories and greenhouses and to the staff of the botanical department for suggestions and criticisms.

From a review of the fragmentary reports on *Rhizoctonia crocorum* DC., we find that it has received some attention as causing a disease of alfalfa, and in one case (19) experiments were planned looking toward a possible means of combating the malady. As a disease of potatoes, reports have been confined to the appearance on the tubers. No survey or cultural work has been undertaken to determine whether or not other plants are serving as hosts for this parasite in America.

### VIOLET ROOT ROT IN EUROPE

While reports of the disease due to this organism are comparatively recent in American literature, the situation in Europe is quite different. There it has been known for almost two centuries as the cause of destructive diseases upon many economic crops, as well as upon numerous wild plants.

For the present study it will not be necessary to attempt even a brief review of the European literature. For an extended discussion of this, the work of Duggar (6) should be consulted. References will be made to some of the leading features of the European results when they have a bearing upon the particular problem in hand. In a summary of the European literature Duggar (6) lists this fungus as parasitic on forty-seven genera, belonging to twenty-one different families of plants, mostly dicotyledons. The first report of this disease came from France (7), in 1728, where it was destroying *Crocus sativus*. From that time the fungus has been noted as attacking such economic crops as asparagus, alfalfa, carrots, red clover, and various other plants in southern and western Europe.

### THE FUNGUS

Many changes in the nomenclature of this fungus have been made as the knowledge of the form has progressed. The lack of a known fruiting stage is, no doubt, responsible for the confusion and difference of opinion regarding the taxonomic position of the organism. A summary of the synonymy has been collated by Duggar. He regards it as unfortunate that *R. crocorum* DC. has priority over the more descriptive name, *R. violacea*, given by the Tulasne brothers (20). The most recent suggestions concerning its name have been made in a paper by Eriksson (8), and are based upon what he believed to be the perfect stages. After having given a review of the distribution of this fungus throughout Europe, Eriksson discussed his experiments with the asparagus and alfalfa forms, which he considered to be separate species. After an extended treatment of the results of this test, which was carried on for one year, he concluded that the violet root rot of the carrot and that of the alfalfa were two entirely different things. This, if true,

throws an interesting light upon the whole violet root rot problem. The experiments carried on by Eriksson are not accepted by all workers as giving conclusive proof of the convictions expressed in his paper. Eriksson's suggestion that biologic forms of this Rhizoctonia exist, and his conclusion that separate species infect carrots and alfalfa, needs to be confirmed by some careful cross inoculation experiments. The field for cultural work to determine whether we have biologic forms of this fungus as Eriksson suggests, and the range of host plants for such forms, if they exist, is as yet unexplored. No doubt the difficulty of securing the fungus in pure culture is responsible for this.

At the close of his paper Eriksson states that he has confirmed, to his own satisfaction, the connection of *R. medicaginis* with *Leptosphaeria circinans* by germination of the Leptosphaeria spores. The germ tubes, which he figures, he considers to be identical with the mycelium of *Rhizoctonis medicaginis*. It is indeed unfortunate that Eriksson did not perform infection experiments with these viable spores and give us the final and necessary test of the connection of the two forms.

## MORPHOLOGICAL CHARACTERS OF THE FUNGUS ON THE POTATO

*Mycelium*. The younger external hyphae are almost colorless. Very soon the cytoplasm develops a faint violet pigment. As the hyphae grow older the walls of the cells become a brownish violet. The color in the walls gradually deepens until the older hyphal strands are a decided violet to buff color. The cytoplasm is conspicuously granular when very young but becomes more vacuolate with age. The young hyphal tips measure 12 to 14 microns in diameter, while the older hyphae measure 7.2 to 10 microns. The long conductive vegetative cells vary in length from 55 to 173 microns. The cells covering the superficial sclerotia are, as a rule, shorter (30 to 50 microns) and thicker (12 to 14 microns) than the cells of the conductive hyphae. In diameter they compare very favorably with the cells of the young hyphal tips. Branching is at right angles. A constriction may appear in the young branch at first but this is not evident in the older strands.

The characters of the internal mycelium are much the same as those of the external mycelium. These strands are septate and branched, the direction of the branching here being determined by the cells of the hosts. Even here there is a distinct tendency of the hyphae to branch at right angles. The internal mycelium on the stem does not differ materially from the superficial external mycelium as to size. There is very little pigment produced after the mycelium enters the host. This feature is conspicuous when an older colored hypha on the surface branches to form an internal hypha under the epidermis. The line of

demarcation of the pigment is rather clear cut. The internal mycelium is intercellular among the loosely associated cortex cells. The young hyphal tips enter some of the host cells and the formation of the internal sclerotia follows. While the mature mycelia of *R. crocorum* and *R. solani* would not be confused, the differences in very young hyphae are not striking.

*Sclerotia.* Within the superficial mantle of mycelium on the surface of the stem there soon appear reddish-black sclerotial bodies. These are longer than they are wide, and in some cases two are formed together, end to end. They appear within eight weeks after the infected tubers are planted and are very numerous on the stem from the ground surface to the seed piece, thirty-three having been counted within a distance of four inches. Surface sclerotia are also numerous at the angles of the roots and on the young rootlets, but always in the mantle of mycelium.

The sclerotia vary from the size of a pinhead, evidently very young ones, to 5 mm. in length. At this stage of development they invariably are longer than they are wide and raised about 1 mm. from the surface of the host. When macerated and examined under the microscope they show cells with all varieties of color from transparent to violet.

The superficial sclerotia are not firmly attached to the host but are connected with all the surrounding mycelial strands. The cells of the hyphae directly joining the sclerotial mass are, as previously described, somewhat thicker and shorter than the cells of the conductive mycelium.

The sclerotial cells proper show the peculiarly branched and curiously lobed condition described by Duggar (6). Under the microscope these cells were seen to be somewhat loosely packed together, giving on the whole, the appearance of a rather spongy, soft mass. In the sclerotia examined, particles of sand were usually included within the young sclerotium. The sclerotium became harder upon drying. This type of sclerotium was not abundant upon the original infected tubers, nor were they conspicuous upon the young tubers on the plants. Rarely was a superficial sclerotium found forming beneath the rudimentary leaves of the tubers.

*Infection cushions.* On badly infected tubers large numbers of small specks the size of a pin head were to be seen with the unaided eye. Transverse sections of a portion of the potato rind showed these to be submerged sclerotial masses from the tops of which many hyphae extended over the surface of the potato and also joined with those from other submerged sclerotia. These infection cushions were very close together, in some cases adjoining or nearly so. The formation of these

infection cushions has been carefully followed both on young stems and young tubers. A young hyphal branch penetrated directly through the wall of a host cell and once inside began to branch profusely. Typical sclerotial cells were formed in the host cell until finally the cell was completely filled by the fungus. The formation of the infection cushions in the young tuber takes place in exactly the same way. Subsequent growth of the fungus compresses the host cells immediately adjoining the sclerotial cells. The host cells in such infected tissue are disorganized. This disorganization increases as the internal sclerotia develop, until finally several cells are broken down and the cavities filled with the fungus mass. The tissue of least resistance lies to the outside of the sclerotial mass, and this is the first to be broken down. However, the pressure of the fungus mass tends to bend the walls of the lower cells downward. Bailey (3) interprets this downward bending as indicating that the fungus has pushed its way in from the surface. The writer has quite a different conclusion insofar as the formation of the infection cushion is concerned. The infection cushions have their beginning in the cork cambium from hyphal strands which have forced their ways to this host tissue by pushing between the cells of the epidermis. Such young infection cushions form in the cork cambium, and, as the cells of the cambium divide a few layers of cork tissue form below the sclerotia. Completely submerged sclerotia were not uncommon even in mature tubers. There is an abundant branching of the hyphae from the top of some of the infection cushions. There appears to be very little spread of the fungus threads from the base of the infection cushions. There is a suberized layer of host cells which stains red with fuchsin. When submerged sclerotia are examined under low magnification this layer gives one the impression of branching from the base of the infection cushion. The young sclerotial cells of the fungus have a dense granular cytoplasm which stains a deep red with both Pianese stain and acid fuchsin.

## THE DISEASE

The disease caused by *Rhizoctonia crocorum* DC. is known as violet root rot, red root rot, or violet Rhizoctonia root rot. As suggested by the common name of the malady the fungus usually confines its attack to the underground parts of the plant. However, in a warm, humid atmosphere in the greenhouse the fungus extended up the stems and to the leaves of some of the potato plants. The favorable moist condition in this case was induced by placing a bell jar over half grown plants. The fungus, which lives in the soil from year to year, progresses slowly, killing patches from one to three rods in diameter in the alfalfa fields.

It has been noted by some observers that the soil where the disease occurred was acid in reaction. While this may favor the rapid development of the fungus, experiments where some infected potatoes were grown in a well limed soil do not seem to indicate that liming would prohibit its growth. The results of these experiments are given in table 2, where potato plants in five pots out of seven developed the disease when the soil was limed.

TABLE 2

*Tabulated results of potato infection*

| POT NO. | SUPPLEMENTARY CROP | DEGREE OF INFECTION | | |
|---|---|---|---|---|
| | | ON STEMS | ON TUBERS | ON ROOTS |
| 1 | Alfalfa | Light—sclerotia small ° | Light | Light |
| 2 | Sugar beets | | | |
| 3 | Radish | Light | | |
| 4 | Carrots | | | |
| 5 | Asparagus | | | |
| 6 | Alfalfa | Light | Light | Light |
| 7 | Sugar Beets | Light | Light | Light |
| 8 | Asparagus | Heavy—many sclerotia | Moderate | Moderate |
| 9 | Carrot | Light | | |
| 10 | Asparagus | Moderate | Moderate | Light |
| 11 | Alfalfa | Light—few sclerotia | Trace | Trace |
| 12 | Sugar beets | Light | Light | Light |
| 13 | Radish | Light | Light | Light |
| 14 | Carrots | Light | Light | Light |
| 15 | Radishes | | | |

## SYMPTOMS OF THE DISEASE

*Symptoms on alfalfa.* The symptoms of the violet root rot on alfalfa have been described by Heald (13), Freeman (9), and others. According to these authors, at first a single plant becomes of a pale yellow color and soon after withers and dies. From this infection center, the fungus spreads in all directions, thus producing dead areas roughly circular in outline. The progress of this fungus, in common with other soil fungi, is slow, varying from three to twenty feet in a single year. In such spots a majority of the plants are killed outright. Practically all attacked plants are reported (9, 13) as losing their tap roots and, if they survive at all, they are not vigorous. In the more heavily affected plants the cortex of the root easily slips away from the vascular cylinder. This stage is followed by a complete rotting of the root which crumbles to pieces when the soil is disturbed.

As the disease progresses in the spots of the alfalfa field we have an area with a dead center surrounded by an area of dying plants, and farther out an area where there is an evidence of a yellowing of the foliage with a paler appearance and sometimes marked chlorosis of the leaves. Considerable wilting is sometimes exhibited at the time of the second cutting and this may come without previously evident symptoms.

The disease is characterized as causing a very rapid death soon after the first symptoms become noticeable. Duggar (6) states that the symptoms on the parts above ground are not striking and were it not for the dead areas in the field it would not be an easy matter to distinguish slightly affected spots.

The appearance of the violet mycelium on the roots is very striking and typical of this disease. The roots are completely enveloped with a crust-like mat of violet mycelium with numerous infection cushions, or sclerotia. Reed and Crabill (19) observed the purple coating to extend downward as much as seven inches on the root, and suggest that it probably extends to a greater depth. Specimens in the herbarium of the University of Nebraska show the Rhizoctonia strands covering the alfalfa tap root fourteen inches below the crown.

*Symptoms on the potato.* Plants from infected tubers planted in the greenhouse February 29, 1920, in a soil free from the disease began to show yellowing and wilting of the lower leaves which arose from the stem below ground. These leaves were covered with the violet felt mycelium which showed all gradations in color, including transparency of the younger tips, pinkish brown, rose brown, and in the older hyphae a violet color. These leaves soon dropped. Outside of this dying of the lower leaves, the plants appeared perfectly healthy and produced a very vigorous top growth. The dying of these leaves could not with certainty be attributed to the attack of the Rhizoctonia.

Plants lifted from the soil nine weeks later, showed the entire underground part of the stem to be covered with the rose brown mycelium which assumed a violet color at the soil surface. These plants were washed in a stream of water and numerous sclerotia were found enmeshed in the superficial hyphae. These could be lifted from the surface of the stem with a needle and showed no connection to the host plant. However, they were deeply entangled in the superficial hyphae from which they arose. The surface hyphae showed a decided tendency to accumulate in strands, proceeding from the infected seed piece upward. While these strands were abundantly connected with transverse hyphae, the fungus showed a marked tendency to progress parallel with the potato stem. This was very striking and quite differ-

ent from that observed upon the original tuber. On the tuber the strands formed a net work which seemed to take no particular direction.

The superficial sclerotia, heretofore mentioned, were rather numerous on the stem. More of them were observed near the ground surface but they were not uncommon on parts deeper down in the soil. There were no evident lesions on the stem of the host. This is very different from a similar attack of *Rhizoctonia solani* which produced long, rather deep lesions, in some cases even extending around the stem, producing a collar rot. When the soil is free from the disease, and infection comes only from the sclerotia on the seed piece, as was the case in this experiment, no conspicuous symptoms of the disease are evident upon the aerial parts of the plant. This may not be true where the soil is thoroughly infected and the plants grown under field conditions.

When the fungus is present in the soil from year to year and can start growing before the potatoes are planted, opportunities for damage are increased. Any serious injury to the under ground part of the plant would undoubtedly be accompanied by above ground symptoms. The tubers, by this time about ½ inch in diameter, began to show the presence of infection cushions (microsclerotia) under the mat of felted mycelium. The root system was very lightly covered with the fungus, but here the hyphae were visible with difficulty to the unaided eye. Occasionally brown specks appeared in the epidermis of the stems and the roots. Microscopic examination showed these to be dead surface cells of meristematic tissue, the injury not extending to the deeper layers of the cortex.

## CLIMATIC REQUIREMENTS

*Moisture relations.* Concerning the moisture requirements of this organism, it is interesting to note the regions from which it has been reported. It has done serious damage in all the countries of western Europe. The disease is reported as developing rapidly under moist conditions in England and France. On the other hand the earliest accounts of the violet root rot disease in America have come from the semi-arid regions of the west. It has been reported outside of this region only within the last decade.

The fact that the disease will develop in the humid areas of Europe, and lately in America, as well as in semi-arid parts of these two continents would indicate that rainfall is not the limiting factor in the spread of the fungus. As a matter of fact, if the organism will thrive under such varied conditions as the reports from this country and Europe show, and attack such an array of hosts as Duggar (6) gives, then it seems that the fungus could adapt itself to many of our important alfalfa, clover, sugar beet, and potato regions.

*Temperature.* It has been noted by observers both in Europe and North America that this disease appeared in alfalfa fields about the time of the second cutting. In some instances July first has been given as the time the disease first makes its appearance. The plants grown in the preliminary experiment which is summarized in table 2, were grown at temperatures between 90° and 100° F. In fact the greenhouse was being used to force Easter flowers during the first half of the experiment. Five other pots grown at temperatures from 60° to 70° F. did not develop the disease. While this test should not be taken as conclusive, because some other uncontrolled factors may have entered into the result, such as moisture, etc., there is some indication that the fungus develops best at high temperature.

*Soil requirements.* This disease has been reported on potatoes in Nebraska from regions of sandy soil. This has also been the case, for the most part, where it has appeared on alfalfa in this state. However, it has developed on alfalfa growing in a loam soil. Many writers have made mention of soil acidity in connection with this disease on alfalfa.

### INFECTION OF THE HOST

*Stem infection of the potato.* The superficial surface hyphae produce branches which infect the host tissue by crowding apart the epidermal cells and forcing an entrance. The hyphae enter through the tender epidermal cells of the young dormant buds. While these may not be the only points of initial entrance for the young infecting hyphae, no others were found in hundreds of sections examined. The growth of the mycelium both external and internal, was greatly stimulated in the regions where the hyphae gained entrance to the host. The internal hyphae pursued an intercellular course which was in general, although by no means exclusively, parallel to the surface strands. Internal branching of vegetative hyphae seemed to be no more abundant than the branching of the surface hyphae. These intercellular hyphae permeated the cortex and finally reached the cambium layer. Young hyphal tips initiated the development of internal sclerotia by passing directly through the wall of a host cell and then branching profusely, or by abundant branching in the intercellular spaces, as previously described.

*Infection of the young tuber.* Early tuber infection follows much the same course as has been described for the entrance of the fungus into the young stem. Many young tubers were examined in all stages of development from slightly enlarged stolon tips to mature potatoes. Here again, entrance of initial infecting hyphae were observed only through the young growing tips such as the stem apex and the "eyes" of the tuber.

The surface cells were forced apart in these regions, and infection took place in a manner exactly as occurred in stem infection. The fungus formed sclerotial cells in the phellogen and these soon broke through to the surface of the tuber. From the exposed surface of this sclerotial cell, hyphae grew out in all directions, joining or fusing with other hyphae from other similarly formed sclerotia or with the superficial hyphae already present on the plant.

*Root infection.* Root infection of both potatoes and alfalfa was accomplished by the young Rhizoctonia hyphae forcing apart the epidermal cells. The hyphae traversed the cortex and finally reached the cambium layer. In the case of the sugar beet the mycelium soon enters the fleshy succulent root and completely destroys it. The carrot meets a similar fate.

In alfalfa and clover the tap roots are rotted away and the plants soon die leaving more or less circular dead areas in the fields. Upon such crops as alfalfa, where the plants are left in the ground over a period of years, the fungus seems to make more headway and destruction is more complete. Furthermore, if the fungus becomes established in such a field, soil treatment cannot be practiced without killing the plants in the area treated.

This disease no doubt causes some injury to the stems, under field conditions. Observations in the field during the season of 1920 revealed a weakening of the potato plants when the roots were badly rotted. The fungus is evidently at a disadvantage upon a short season crop like potatoes, and the field losses are, as yet, minor in potato fields.

Perhaps the most serious loss to the potato comes while the tubers are in storage. Heavily infected tubers have the periderm broken by the infection cushions and in some cases this breaking is so complete as to split off large portions of the outer skin. This subjects the tubers to drying out. In England, where storage conditions of tubers affected with this disease have been under observation for a number of years, the tubers are reported (1) to become soggy and spongy if kept any considerable length of time. "The mycelial strands originating from the small sclerotia ramify abundantly in the internal tissues, causing a rot which soon reduces the tuber to a pulp."

### INOCULATION EXPERIMENTS

Infected tubers covered with the violet felt mycelium were planted in 4-gallon pots in the greenhouse. The soil in eight of the pots was slightly acid in reaction. The soil in the remaining seven pots was well limed. The tubers were planted late in February. Some of the stems were taken for study six weeks later. At that time they were

well covered with the violet mycelium but no sclerotia had formed. Sclerotia were abundant at the end of nine weeks and from these fresh sclerotia isolation experiments were begun with the hope of securing pure cultures of the organism. The results of this work will be reported later.

At the end of the fourteenth week all the potato plants were dug. The infection results are given in table 2. The supplementary crops planted in the pots were alfalfa, sugar beets, radishes, carrots and asparagus. All of these have been reported as susceptible to the violet root rot.

Pots numbered 5–6–7–9–10–11 and 15 were well limed. Liming gave no marked results upon the inhibition of infection. and no noticeable difference in the growth of the host.

The results of the cultural work, as given in the table, show that the disease may be spread by planting the infected tubers. Since the number of "seed" tubers was limited no attempt was made to determine the effect of various seed treatments upon infected tubers when planted in a soil free from this fungus.

Further work must be done before any conclusions can be drawn upon the infection of the supplementary crops here grown.

SUMMARY

1. The violet root rot disease is present in the most important potato growing regions of Nebraska. The disease is of minor importance at present but may become more serious in time.

2. The disease can easily be introduced into new localities by planting infected tubers.

3. Further tests should be made to determine whether the causal organism is identical with that causing a similar disease on alfalfa and sugar beets.

4. Severe infection on the tubers result in a breaking of the periderm which subjects the potato to drying out in storage.

5. This breaking of the periderm is due to the formation of infection cushions below the epidermis which break through to the surface.

6. Cultural experiments to secure pure cultures of the organism are under way.

ESTACION EXPERIMENTAL DE HAINA,
SANTO DOMINGO, DOMINICAN REPUBLIC.

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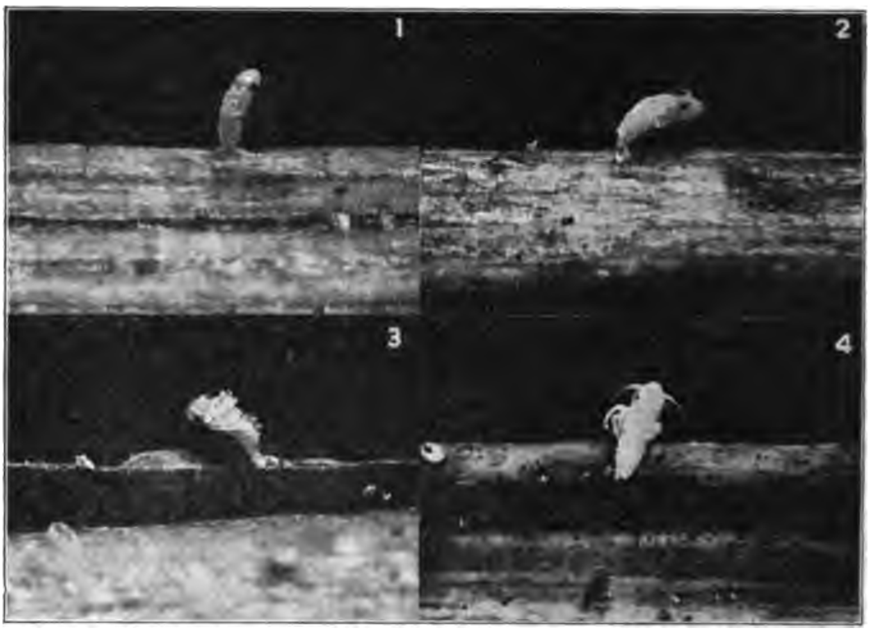
# MINIMUM INCUBATION PERIODS OF CAUSATIVE AGENT OF CURLY LEAF IN BEET LEAFHOPPER AND SUGAR BEET

HENRY H. P. SEVERIN

WITH FOUR FIGURES IN THE TEXT

A method of obtaining beet leafhoppers (*Eutettix tenella* Baker) non-infective as to curly leaf (curly top or blight) was first reported in literature by Stahl and Carsner (3). During the process of hatching (Figs. 1–3), the nymphs were transferred with a camel's-hair brush from a curly leaf to a healthy beet and the hoppers failed to produce the disease.




FIGS. 1–4. PROCESS OF HATCHING OF BEET LEAFHOPPER (*Eutettix tenella*)

Fig. 1. Nymph enclosed in chorion, amniotic and vitelline membranes issuing from egg-slit in petiole of beet leaf.

Figs. 2–3. Nymphs after extrication from embryonic envelopes.

Fig. 4. Nymph ready to crawl away. Nymphs in the process of hatching as in figures 1–3, when transferred with a camel's-hair brush from a curly leaf to a healthy beet, failed to produce the disease.

Curly leaf is not transmitted through seeds from "stechlinge" infected with the disease before or after transplanting. The following figures indicate the number of beets grown from such seeds and kept under observations for a period of five months in the greenhouse:

18,154 beets grown from seeds obtained from "stechlinge" blighted before transplanting.
4,232 beets grown from seeds gathered from "stechlinge" infected with curly leaf after transplanting.
352 beets grown from seeds taken from mother beets showing curly leaf symptoms.

22,738

A total of 22,738 beets were grown from blighted seed beets but not a single case of curly leaf developed.

### MECHANICAL CARRIER

There is no evidence to show that the beet leaf-hopper is a mechanical carrier of curly leaf. Non-infective nymphs fasted over night, were allowed to feed the next morning on the lower surface of beet leaves showing an advanced stage of curly leaf,—namely the nipple-like papillae and knot-like swellings on the distorted veins. With the use of a hand-lens one could readily see the hopper force its mouth-parts into the leaf as its body swayed from side to side. After each nymph had fed on a diseased leaf from 1–2 minutes, the hopper was disturbed in its meal and transferred to the innermost or youngest leaf of a healthy beet-seedling, where it was allowed to feed for five minutes or less if it completed its meal before the end of that time. This experiment was repeated 44 times; 21 nymphs were used during the first day and 23 nymphs during the second day. Negative results were obtained with 44 beets.

At the end of each day the nymphs were confined in two cages, each enclosing a healthy beet to determine whether they were capable of causing the disease. The 21 nymphs caused a typical case of curly leaf but the 23 nymphs failed to transmit the disease at the end of 40 days. It is evident that the beet leafhopper can become infective by feeding from 1–2 minutes on a blighted beet.

### MASS INFECTION

The beet leafhopper is not a mechanical carrier of curly leaf in mass infection of a sugar beet. The method of conducting this experiment was somewhat similar to the preceding except that more nymphs were used and the time of feeding was increased to 5 and 10 minutes on the leaves of curly leaf and healthy beets respectively. Three nymphs were transferred from the foliage of a blighted beet to each leaf of a healthy beet seedling and from 6–21 nymphs were used on one plant. This experiment was repeated with 12 beet seedlings and 131 nymphs, but not a single case of curly leaf developed. A lot of 33 of the 131 nymphs were kept in a cage enclosing a healthy beet to determine whether they became infective. This lot developed a typical case of curly leaf, but five other

batches failed to transmit the disease. It is evident that the beet leafhopper rarely becomes infective by feeding five minutes on a blighted beet.

### MINIMUM INCUBATION PERIOD OF CAUSATIVE AGENT OF CURLY LEAF IN BEET LEAFHOPPER

According to Smith and Boncquet (2) the beet leafhopper "does not mechanically transfer the pathogenic factor" when allowed to feed three hours on a curly leaf beet and then transferred for three hours on a healthy beet, or an incubation period of six hours of the disease-causing factor in the insect. The incubation period of the inciting agent of curly leaf in the leafhopper "was no more than 48 and possibly not over 24 hours."

Curly leaf was occasionally produced by an incubation period of 4–6 hours of the causative agent in the beet leafhopper under high temperatures in the greenhouse from April to July. The method used was to confine 25 or 50 non-infective males in cages enclosing curly leaf beets from 1–5 hours, or the adults were previously fasted in empty cages from ½–3 hours, and then allowed to feed from ½–4 hours on blighted beets. These beets showed either the earliest visible symptom of curly leaf,—namely the transparent network of minute veins, or the advanced stage of the disease already described. The cages containing the leafhoppers were then transferred successively to healthy beet seedlings at the end of ½, 1, or 2 hours and in some cases after 24 and 48 hours. In each experiment the insects were finally kept in a cage enclosing a healthy beet seedling for a period of two weeks or longer to determine whether they became infective. Eight typical cases of curly leaf developed of 60 beets used in the following short incubation periods:

| | | | |
|---|---|---|---|
| Incubation period 4 hrs. | Max. 103° F. | Min. 94° F. | Mean 100° F. |
| " " 5 " | " 116° F. | " 84° F. | " 102° F. |
| " " 5 " | " 116° F. | " 84° F. | " 102° F. |
| " " 5 " | " 120° F. | " 104° F. | " 113.5° F. |
| " " 5 " | " 120° F. | " 104° F. | " 113.5° F. |
| " " 5 " | " 120° F. | " 104° F. | " 113.5° F. |
| " " 5 " | " 122° F. | " 108° F. | " 115.6° F. |
| * " " 6 " | " 119° F. | " 84° F. | " 104° F. |

* In one experiment 25 males with an incubation period of five and six hours caused successive infection in two beets.

Thirty-six batches of 25 or 50 beet leafhoppers with an incubation period of 1–3 hours of the causative agent of curly leaf, failed to transmit the disease to 36 beets. The incubation period from 7–10 hours gave negative results with 29 beets, when the males were allowed to feed one hour on each healthy beet at a mean temperature of 90° F. The incubation period of 24 hours was repeated 11 times and resulted in six curly leaf beets. The experiment with an incubation period of 48 hours was

performed 10 times and seven cases of curly leaf developed. Forty-three lots of 25 or 50 males, confined in cages enclosing healthy beets for a period of two weeks or more, caused curly leaf in 42 beets,—only a single batch of hoppers remained non-infective after feeding one hour on a blighted beet.

Curly leaf was not produced by an incubation period of 1–10 hours of the causative agent in the beet leafhopper under lower temperatures (maximum 80–86° F.) in the greenhouse during October and November. The incubation periods of 17–24, and 48 hours gave negative results with 31 beets at the following temperatures: maximum 80–86° F.; minimum 48–62° F.; mean 67–73° F.

There may be other factors besides temperature, however, which may play an important role on the duration of the incubation period of the inciting agent of curly leaf in the leafhopper In the fog belt districts of Orange County we (1) are inclined to believe that the symptoms of curly leaf do not always appear on the leaves due to a dormant or latent condition of the disease-producing factor in the beet. The usual period of 1–2 weeks for the first visible symptom of curly leaf to appear under high temperatures is often prolonged to over a month or more during the winter in the greenhouse at Berkeley.

### MINIMUM INCUBATION PERIOD OF CAUSATIVE AGENT OF CURLY LEAF IN SUGAR BEET

The minimum incubation period of the causative agent of curly leaf in the sugar beet was found to be five days. The method employed was to allow 50 infective males to feed on a healthy beet for one day on March 31. The next day the 50 specimens were removed and 300 non-infective adults were confined in the cage enclosing the infected beet. Twenty leafhoppers were removed daily from the infected beet and transferred to a healthy beet seedling on which they fed for a period of three months. A similar experiment was performed with 50 infective males and 300 non-infective nymphs. In the first experiment the original infected beet showed the earliest visible symptom of curly leaf on April 9, and in the second experiment on April 11. The results are indicated in table 1.

According to table 1, the adults became infective by feeding on the beet five days after it was infected and the nymphs at the end of eight days. A glance at table 1, shows that 20 adults which were transferred to a healthy beet on April 7, after feeding seven days on the infected beet, failed to transmit curly leaf. It is evident that non-infective hoppers became infected by feeding on a sugar beet infected with curly leaf before the cleared veinlets on the youngest leaf appeared on April 9, 11.

Experiments similar to the preceding were repeated 10 times and in one other case the incubation period of the causative agent of curly leaf

in the sugar beet was five days at the following temperatures: maximum 108° F.; minimum 51° F.; mean 71.7° F. The infected beet showed the first visible symptom of curly leaf at the end of 10 days.

In the next experiment instead of the nymphs and adults feeding separately on two infected beets as in the first experiment, both were confined in a cage enclosing a single beet, infected one day previously by 50

TABLE 1

*Incubation periods of causative agent of curly leaf in sugar beets*

| Dates, 20 nymphs and 20 adults were transferred to healthy beets | Dates curly leaf developed (adults) | Dates curly leaf developed (nymphs) | Temperature | | |
|---|---|---|---|---|---|
| | | | Max. °F. | Min. °F. | Mean °F. |
| (Mar. 31) | | | 86 | 56 | 71 |
| Apr. 1 | | | 96 | 58 | 77 |
| Apr. 2 | | | 80 | 50 | 65 |
| Apr. 3 | | | 104 | 56 | 80 |
| Apr. 4 | | | 108 | 50 | 79 |
| Apr. 5 | May 4 | | 88 | 50 | 65 |
| | | | 93.6 | 53.3 | 72.8 |
| Apr. 6 | Apr. 22 | | 86 | 52 | 69 |
| Apr. 7 | | | 86 | 50 | 68 |
| Apr. 8 | May 29 | June 4 | 100 | 48 | 74 |
| | | | 90.6 | 50 | 70.3 |
| Apr. 9 | Apr. 26 | Apr. 24 | 92 | 52 | 72 |
| Apr. 10 | May 3 | Apr. 20 | 86 | 54 | 70 |
| Apr. 11 | | Apr. 27 | 95 | 51 | 73 |

infective males. Twenty adults and 20 nymphs were removed daily from the infected beet and transferred to cages enclosing two healthy beet seedlings. The original infected beet showed the first visible symptom of curly leaf nine days later, but the adults became infective at the end of seven days (maximum 119° F., minimum 46° F.; mean 71° F. temperatures) and the nymphs at the end of nine days (maximum 119° F., minimum 46° F., mean 76.4° F. temperatures) coincident with the appearance of curly leaf in the infected beet.

Before molting insects stop feeding and empty the contents of the alimentary canal. During the process of molting the chitinous intima of the fore and hind-intestines as well as the ducts of the salivary glands are shed. The nymphs, however, do not lose their infectivity during the process of molting, so this would hardly explain the longer period by the nymphs to become infective.

Mr. C. C. Epling in his thesis work found that the incubation period of the disease-producing agent of curly leaf in "stechlinge" and beets about three months old was prolonged during the winter. The nymphs became infective at the end of 15 days (maximum 102° F.; minimum 58° F.; mean 72° F. temperatures) by feeding on a "stechling" infected by 50 infective adults. The infected "stechling" developed curly leaf at the end of 16 days. In the case of beets about three months old, the nymphs became infective at the end of 15 days (maximum 94° F.; minimum 58° F.; mean 71.7° F. temperatures) and the infected beet showed the transparent venation of curly leaf at the end of 14 days.

During the past three years the work on the beet leafhopper and curly leaf was conducted in cooperation with the departments of Entomology and Plant Pathology of the University of California.

## SUMMARY

The beet leafhopper when it hatches from the egg is non-infective.

Curly leaf is not transmitted through the seeds from "stechlinge" affected with the disease before and after transplanting.

The beet leafhopper is not a mechanical carrier of curly leaf, nor a mechanical carrier in mass infection of a beet.

The minimum incubation period of the causative agent of curly leaf in the beet leafhopper required four hours at the following temperatures: maximum 103° F.; minimum 94° F. and mean 100° F. and five days in the sugar beet at the following temperatures: maximum 93.6° F.; minimum 53.3° F. and mean 72.8° F.

CALIFORNIA AGR. EXP. STATION.

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## BRIEFER ARTICLES

### THE FALSE MILDEW OF TOBACCO INTRODUCED INTO THE UNITED STATES FROM THE DUTCH EAST INDIES?

B. T. Palm

In a recent publication Smith and McKenney[1] have described in some detail the occurrence in the United States of America for the first time on tobacco of a dangerous tobacco parasite, *Peronospora hyoscyami* DeBary. As the disease is causing considerable anxiety in the infected tobacco districts the authors discuss the possible means by which the introduction of the fungus in question has been brought about.

After stating that *Peronospora hyoscyami* has been reported to attack *Hyoscyamus niger* in Europe, tobacco in Australia and South Africa and *Nicotiana glauca* in California and Texas, they proceed (p. 4):

"No definite statement as to the probable means of introducing the disease into the United States can be made at present. However, it must be borne in mind that the mats used in baling tobacco in this region are imported annually from Sumatra, arriving in the month of September, about the time the harvested seed is being cleaned and stored away. It is known that certain insects have been introduced into the United States on such mats and it is not impossible that this disease may have been introduced into the United States through this agency, especially as many of the mats are second hand, having been previously used on East-Indian tobacco." "On the other hand," they suggest, "the disease may have come into Florida by the way of California and Texas or from the south Atlantic or Gulf seaboard where *Nicotiana glauca* also grows."

The importance of the disease in question makes it necessary to elucidate the sources of importation and therefore it may not be superfluous to discuss once more the chances for an importation of the fungus, by means of the so-called Sumatra tobacco mats.

The mats used in packing tobacco are manufactured from one or more species of sedge grass either cultivated or collected in the wild by the natives in the low swampy plains of South Borneo. As far as the writer has been able to ascertain during a visit to that part of Borneo no tobacco is cultivated there. The new mats are then shipped from Bandjermasin, the harbour town of South Borneo, to the United States of America directly or via Holland. It does not seem very likely then that in this way a parasite of the Peronospora type could be introduced.

The second hand mats have another history.

[1] Smith, Erw. F. and R. E. B. McKenney. A dangerous tobacco disease appears in the United States. U. S. Dept. of Agriculture, Circular 174. April, 1921.

Shipped from Bandjermasin to Java or Sumatra, they are stored on the tobacco estates there. After baling of the tobacco on the estates every package as a rule is disinfected with carbon dioxide (150 ccm[3] p. M[3] for 48 hours) against Lasioderma. The bales then are shipped to Holland where they are stored in the tobacco warehouses awaiting the auction sales. From Holland the tobacco packages go to the United States, where the mats are sold to the tobacco growers.

An introduction of the tobacco Peronospora through the intermediary of the second hand mats would, theoretically, be possible in three ways: from the Dutch East Indies (Java and Sumatra), by contamination during shipping, and from Holland.

The first possibility can from our present state of knowledge not be absolutely discarded; the chances seem, however, very small as *Peronospora Hyoscyami* as yet has not been found on tobacco and, as far as I know, on no other plant in the Dutch East Indies.

Thus far, no genuine species of Peronospora has, as far as the knowledge of the writer goes, ever been found in the Dutch East Indies. In view of this, it is true, negative evidence Java and Sumatra will probably not prove to be the place of origin of the tobacco "blue mold" found in the United States. The tobacco diseases in Java and Sumatra have been rather extensively studied during the last twenty years and it's not very probable that a Peronospora of tobacco would have escaped notice for so long a time. The writer himself has during more than five years, as pathologist, repeatedly visited the various tobacco districts in Java and during the last year made a special survey of the Sumatra tobacco diseases, without having been able to find the tobacco Peronospora, either on tobacco or wild Solanaceae.

The possibility of contamination of the packing mats during shipment by tobacco from other countries might not, at present, be wholly disregarded. However, as a rule every possible precaution is taken to exclude other cargo from the rooms where Sumatra and Java tobacco has been stowed, this principally to avoid contamination *en route* by Lasioderma. There is every reason to think, therefore, that tobacco from other tropical countries, as British North Borneo, China and British India—which perchance may be shipped on the same ships as Dutch East Indian tobacco—also will be kept separated from the latter.

There remains now to be considered the third stage during the transportation of the mats where a contamination might take place, that is in Holland. During storage in the warehouses there, tobacco from other countries as Brazil, Asia Minor and Europe might occasionally come into contact with the Dutch East India tobacco. It is of course very difficult to estimate the chances for an infection. Taking into consideration,

however, that such a long distance spread of Peronospora in this case as well as during shipping must be solely based on a contamination by resting spores which may adhere to the bales, the chances would seem exceedingly small for an infection to be brought about in this manner.

The evidence brought forward above is decidedly not in favour of the theory of an introduction of *Peronospora Hyoscyami* De Bary into the United States from the Dutch East Indies by means of second hand tobacco mats even if it can not at present be absolutely disproved. The second theory advanced by Smith and McKenney, namely that *Peronospora Hyoscyami* has been introduced into Florida either from California and Texas from where this fungus already has been reported or from the South Atlantic or Gulf seaboard where *Nicotiana glauca* grows, would, however, appear to be the more plausible one.

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MEDAN, SUMATRA, DUTCH EAST INDIES.

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## EFFECT OF FERTILIZERS AND LIME ON CONTROL OF TOMATO LEAF SPOT (SEPTORIA LYCOPERSICI)

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WITH SIXTEEN FIGURES IN THE TEXT

### INTRODUCTION

Observations and experiments covering a period of nearly 60 years seem to indicate that fertilizers and lime may be used to increase or decrease the amount of disease in a crop. The processes by which fertilizers bring about these changes, however, still need investigation. Sheldon (21, 22), Peltier (16), and Fromme and Murray (8) believe that treatments or conditions that cause a vigorous growth make the plants more susceptible to disease while those that delay or retard growth make them more resistant. Support of this view seems to be found, in part at least, in the results of Liebig (11), Roberts (18), Laurent (10), Marchal (14), Delacroix (3), McAlpine (12), Spinks (23), McCue and Pelton (13), Butler (2), and Thomas (25), who reported increased susceptibility to rust, mildew, and other foliage diseases from the use of nitrogenous fertilizers and manures. In most of these cases it was assumed that succulence of the tissues caused by nitrogen facilitated parasitic invasion.

Another current interpretation of fertilizer effects on disease resistance is that they modify the acidity of the soil and cell sap and thereby affect the activities of the parasites. In the case of soil inhabiting parasites this is quite obvious. The ginseng root-rot fungus, *Thielavia basicola*, as reported by Whetzel (30), is easily controlled by applying phosphate, especially acid phosphate to the ginseng beds. An acid soil also helps to control potato scab. On the other hand, the club root organism, *Plasmodiophora brassicae*, as reported by Stewart (24) and by Hendrick (9), may be largely controlled in cabbage and turnip fields by the use of lime.

That the acidity of the plant sap can be modified by the acidity of the soil has been reported on the basis of experiments, by Truog (27) and by Truog and Meacham (28). If these results should be substantiated by future investigations, it would seem that fertilizer ingredients that increase the acidity of the soil may also increase the acidity of the cell sap.

Delacroix (4) believes that phosphate inhibits disease by increasing the acidity of the cell sap, and Wagner (29) reports that the acidity (hydrogen-ion concentration) of plants injected with pathogenic bacteria rises simultaneously with the appearance of the first disease symptoms. These results would therefore seem to indicate that this is a means by which the plant protects itself against the action of parasites.

The use of phosphates for the control of plant diseases has given somewhat variable results. Laurent (10), Delacroix (4), Spinks (23), and McCue and Pelton (13) found that it increased resistance while Marchal (14), and Butler (2), and in one instance Laurent (10), found that it decreased it. These discrepancies may be due to peculiarities of the different organisms worked with or to variable effects of phosphates on different soils.

Lime has been reported by Ducomet (5) and by Delacroix (4), to decrease disease resistance, and by Marchal (14), Ramsbottom (17), and Thomas (25), to increase it. Notwithstanding the fact that Truog (27), Truog and Meacham (28), and Parker and Truog (15) have shown that it plays an important role in neutralizing and precipitating acids formed in protein metabolism, it is doubtful in view of these conflicting reports on disease control what influence, if any, it has on disease resistance.

The use of potash seems to have given more uniform results in the control of plant diseases than any other fertilizer ingredient. Marchal (14), Spinks (23), Russell (19), Finlow (6), and Butler (2), have published fairly reliable evidence on its effect in decreasing disease. Whether its action is due to the production of firmer tissues which tend to resist parasites or to an increased acidity of the cell sap and protoplasm has not been determined. Increased acidity of tomato fruits from the use of potash, as reported by Patterson (1) and by Tracy (26), would seem, however, to support the latter view.

## INVESTIGATION

As tomato fields in the East and Middle West, where tomatoes are commonly grown for canneries, are badly infested by the tomato leaf spot fungus (*Septoria lycopersici*), the writers carried on numerous greenhouse experiments to determine whether certain quantities and ratios of fertilizers and lime may be used to help control this disease.

## MATERIAL AND METHODS

The experiments were run in a number of different sets, each of which consisted of several fertilizer groups and a control group. Twenty-five plants were used in each group. One batch of medium fertile, friable, loam soil thoroughly mixed and sifted was used for all of the pot experiments.

Sodium nitrate (15.65% N), potassium sulphate (48% $K_2O$), and acid phosphate (16% available $P_2O_5$) were used in varying quantities both without other fertilizers and with a constant quantity of other fertilizer ingredients. All quantities of fertilizers used were calculated on the basis of parts per million of soil. Copper sulphate was also used in two sets of experiments.

The acid phosphate and lime were pulverized in a mortar and mixed with the sifted soil before it was potted: the sodium nitrate and potassium sulphate were dissolved in water and added to each pot by means of a pipette.

The plants receiving varying quantities of sodium nitrate were grown in jelly glasses; the others, in clay pots with closed bottoms.

All groups within a set were started on the same day by planting in the pots small tomato seedlings in the second leaf and keeping them moderately moist.

All the plants of each set were also inoculated with *Septoria lycopersici* at one time and kept in a moist chamber 48 to 60 hours and then transferred to benches in the greenhouse. One batch of spore material kept thoroughly mixed by frequent shaking was applied as uniformly as possible to all plants of a set by means of a compressed air sprayer. The initial infections were counted the eleventh day after inoculation.

The leaf areas and number of infections per plant and per unit area of leaf surface were recorded for both the treated plants and the controls.

The average leaf area per plant for each group of a set was determined by making leaf tracings of three average plants of each group and by measuring the tracings by means of a planimeter. One-third of the total leaf area of the three plants was used as the average leaf area per plant for the group.

## RESULTS OF EXPERIMENTS

In figures 1 to 16 the controls are represented in the vertical columns marked zero. They received either no fertilizer as shown in figures 2, 4, 6, 8, 10, 12, 14, and 16 or uniform quantities of certain fertilizers used as constants for both the controls and treated plants, as noted in the headings of the other figures. The treated plants received nitrate, phosphate, or potash at the rates of 50, 150, 300, and 500 parts per million of soil, or lime or copper sulphate at the rates specified at the bottom of the graphs for these substances.

The graphs composed of broken lines connecting the dots show the relationship between the controls, which received no fertilizer variant, and the treated plants. Each dot expresses the average leaf area or number of infections per plant or per square inch of leaf surface for a

group of 25 plants. The continuous lines indicate the directions of the graphs.

*Relationship between leaf area and number of infections per plant.* The effect of nitrate, as shown in figures 1 and 2, was to increase both the leaf area and the number of infections per plant. Acid phosphate increased the leaf area and the number of infections per plant in three sets of experiments (Figs. 3, 5, 6) and decreased them in another (Fig. 4). Positive correlation between leaf area and number of infections per plant was also obtained for potash (Figs. 13, 14), for two sets of experiments with air-slaked lime (Figs. 7, 8) and for one with copper sulphate (Fig. 15). The exceptions in the few remaining sets of experiments are probably due to experimental error. These experiments therefore seem to indicate that fertilizers either augment or diminish the number of infections per plant by altering the leaf area.

*Relationship between growth and susceptibility to infection.* It might be assumed on the basis of the foregoing evidence that when the plants are uniformly inoculated and kept in an environment favorable for infection the number of infections per plant depends wholly on the amount of leaf area that may be infected were it not for the fact that a similar relationship seems to obtain between area of the leaves and number of infections per square inch of leaf surface. In figures 2, 3, 5, 7, and 14, for instance, leaf area and number of infections per unit area of leaf surface were increased while in figures 4, 8, 13, and 15 both were decreased.

TABLE 1

*Effect of fertilizers and other substances applied to the soil on the development of tomato leaf spot.*

| TREATMENT | SQUARE INCHES OF LEAF AREA PER PLANT | | INFECTIONS PER PLANT | | INFECTIONS PER SQUARE INCH OF LEAF SURFACE | |
|---|---|---|---|---|---|---|
| | AVERAGE NUMBER | INCREASE IN PERCENTAGE | AVERAGE NUMBER | INCREASE IN PERCENTAGE | AVERAGE NUMBER | INCREASE IN PERCENTAGE |
| Nitrate | 54.2 | 77 | 279 | 55 | 5.1 | -13 |
| Control | 30.6 | | 180 | | 5.9 | |
| Phosphate | 81.8 | 14 | 341 | 50 | 4.1 | 32 |
| Control | 71.8 | | 226 | | 3.1 | |
| Lime | 63.2 | -2 | 239 | -8 | 3.7 | -7 |
| Control | 64.4 | | 261 | | 4.0 | |
| Potash | 55.0 | -19 | 309 | -46 | 5.6 | -33 |
| Control | 68.0 | | 573 | | 8.4 | |
| Potash* | 54.6 | 6 | 741 | 77 | 13.5 | 68 |
| Control | 51.6 | | 417 | | 8.0 | |
| Copper Sulphate | 100.0 | -20 | 227 | -17 | 2.3 | 4 |
| Control | 125.6 | | 275 | | 2.2 | |

* As the increased number of infections in this set of experiments is out of all proportion to the increase in leaf area this set was not averaged with the preceding one.

The relationship between leaf area and number of infections per plant and per unit area of leaf surface may also be seen in the summary of the results in table 1 in which is recorded the average of all groups of plants receiving the same fertilizer or other variant and the average of the controls for these groups.

The correlation between growth, as measured by leaf area, and number of infections per plant is clearly brought out in the above table. The correlation between leaf area and number of infections per unit area of leaf surface is also obvious although not so well supported in the summary of the nitrate and copper sulphate treatments as in the separate graphs. When the impossibility of inoculating all groups of plants uniformly is considered, it is not surprising that there are some exceptions. It would therefore seem that conditions favorable for growth not only increase the leaf area and thereby produce more surface for infection but also increase the susceptibility of the plants to disease, while conditions that hinder growth reduce susceptibility.

## DISCUSSION

No fertilizer or other substance used seemed to increase or decrease the susceptibility of the tomato plants to leaf spot except as it affected growth or the internal conditions accompanying growth. This was true also of the different ratios and quantities of fertilizers used.

As the plants used in the foregoing experiments were heavily inoculated and kept under ideal conditions for infection, the number of initial infections is much higher than would ordinarily occur naturally in the field in the early part of the growing season. The contrast would also be more marked in the secondary infections as the more heavily infected plants would produce the more spores. Moreover, in the field the larger and heavier plants would hold rain and dew longer and therefore afford better opportunities for infection. It is therefore obvious that excessive vegetative growth should be avoided.

It is somewhat difficult to compare the results of these experiments with those previously published as most previous experiments of this kind were made on a different basis and the results were expressed either as general conclusions or as percentages of infection. Although Thomas (25) has published his results in the form of numbers of infections per plant or per leaf he has published no data on number of infections per unit area of leaf surface. In fact some of these previous reports contain only observations made on plats or fields in which different fertilizers were used primarily for another purpose. The data, as might be expected, under such circumstances, is therefore scanty. Not only were the crops and parasites different but the infections were often of such a

spreading nature that a single infection of a leaf was ultimately equivalent to several infections. However, the interpretation of the effects of fertilizers in the present experiments would explain nearly all results previously published and also account for most of their apparent discrepancies.

As it has been found by Truog and Meacham (28), that high acidity (hydrogen-ion concentration) of the cell sap frequently restricts the growth of plants while a lower acidity favors growth, it might be assumed that the relationship between growth and infection is really a relationship between acidity and resistance. But as Haas (8) and others have shown that the total acidity (undissociated and dissociated) of plant cells is usually much greater than the dissociated acidity (hydrogen-ion concentration), it would seem that the neutralization of acid in the cell sap by lime or other substances would have very little effect on the hydrogen-ion concentration, for as soon as some of the free acid were precipitated more would immediately become dissociated. Nevertheless if dissociation of acids in plant cells does not take place so rapidly as assumed, hydrogen-ion concentration may have an important bearing on susceptibility to disease. It is doubtful, however, whether it is the plant's sole means of resisting parasites although it may be comparable to the serum of the blood in inhibiting animal diseases.

Although fertilizers apparently affect susceptibility of plants to disease and may be so used as to avoid conditions favorable for excessive infection, they do not seem to provide a sufficient means for the control of tomato leaf spot.

## SUMMARY

Different quantities and ratios of sodium nitrate, potassium sulphate. acid phosphate, air-slaked lime, and copper sulphate were used in pots of soil to determine their effect on the control of tomato leaf spot. Treatments with these substances either increased or decreased the leaf area and thereby caused a corresponding alteration in the number of infections per plant. These alterations in leaf area were also correlated with similar alterations in number of infections per unit area of leaf surface. Favorable conditions for growth therefore increased susceptibility to infection while unfavorable conditions decreased it.

The relationship between plant growth and acidity of the cell sap reported by Truog (27, 28) and his associates may have an important bearing on susceptibility to infection, for number of infections per unit area of leaf surface is positively correlated with growth and growth, as shown by Truog (27) is, at least in some cases, inversely correlated with the acidity of the cell sap.

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## DESCRIPTION OF FIGURES

FIG. 1. Effect of increased quantities of sodium nitrate and constant quantities of acid phosphate and potassium sulphate.

FIG. 2. Effect of varying amounts of sodium nitrate in the absence of other fertilizers.

FIG. 3. Effect of increased quantities of acid phosphate and constant quantities of sodium nitrate and potassium sulphate.

FIG. 4. Effect of varying amounts of acid phosphate in the absence of other fertilizers.

FIG. 5. Effect of increased quantities of acid phosphate and constant quantities of sodium nitrate and potassium sulphate.

FIG. 6. Effect of varying amounts of acid phosphate in the absence of other fertilizers.

FIG. 7. Effect of increased quantities of airslaked lime and constant quantities of acid phosphate, sodium nitrate, and potassium sulphate.

FIG. 8. Effect of varying amounts of air-slaked lime in the absence of fertilizers.

FIG. 9. Effect of increased quantities of air-slaked lime and constant quantities of acid phosphate, potassium sulphate, and sodium nitrate.

FIG. 10. Effect of varying amounts of air-slaked lime in the absence of fertilizers.

FIG. 11. Effect of increased quantities of air-slaked lime and constant quantities of acid phosphate, potassium sulphate, and sodium nitrate.

FIG. 12. Effect of varying amounts of air-slaked lime in the absence of fertilizers.

FIG. 13. Effect of increased quantities of potassium sulphate and constant quantities of acid phosphate and sodium nitrate.

FIG. 14. Effect of varying amounts of potassium sulphate in the absence of other fertilizers.

FIG. 15. Effect of increased quantities of copper sulphate and constant quantities of acid phosphate, potassium sulphate, and sodium nitrate.

FIG. 16. Effect of varying amounts of copper sulphate in the absence of fertilizers.

FIG 1 NITRATE VARIANT
AP 100 ppm
$K_2SO_4$ 100 ppm

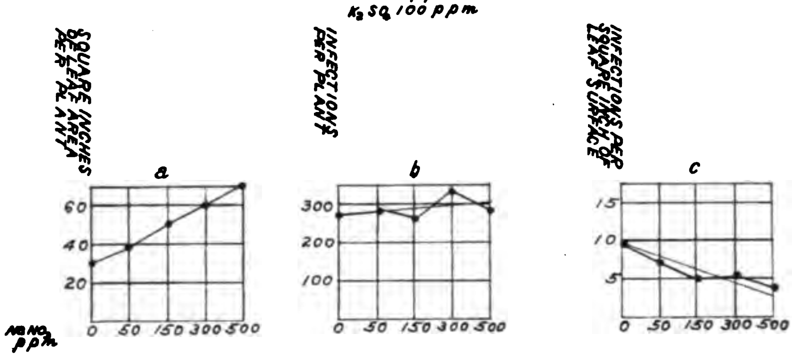



FIG 2 NITRATE VARIANT

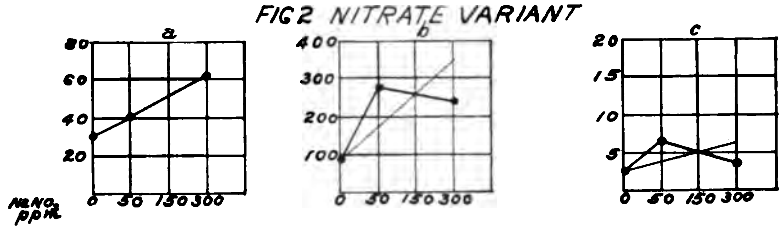



FIG 3 PHOSPHATE VARIANT
$NaNO_3$ 100 ppm
$K_2SO_4$ 100 ppm

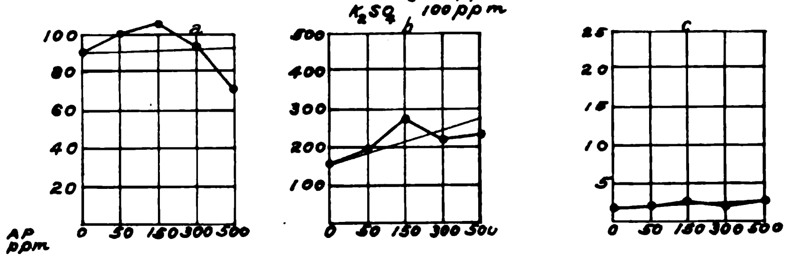



FIG 4 PHOSPHATE VARIANT

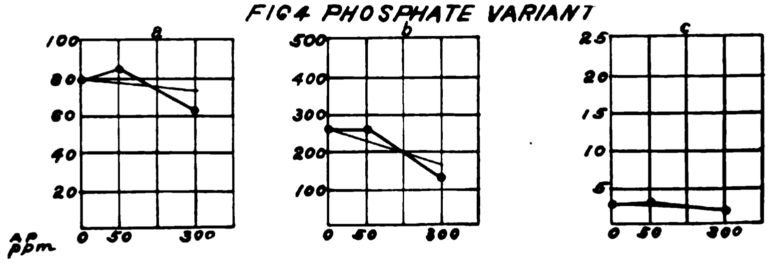


FIG 5 PHOSPHATE VARIANT
$NaNO_3$ 50 ppm
$K_2SO_4$ 50 ppm

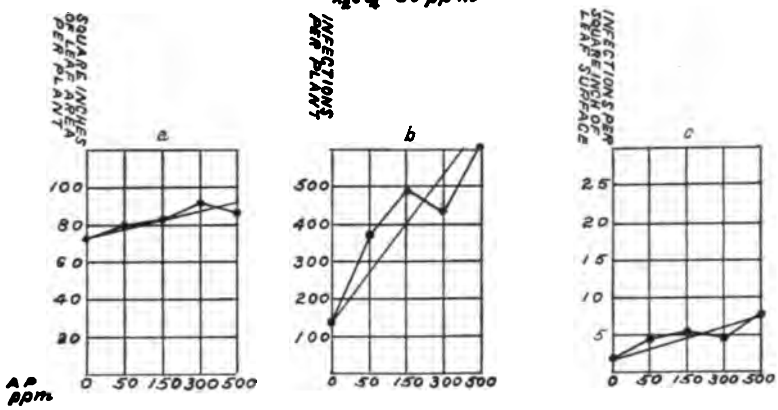



FIG 6 PHOSPHATE VARIANT

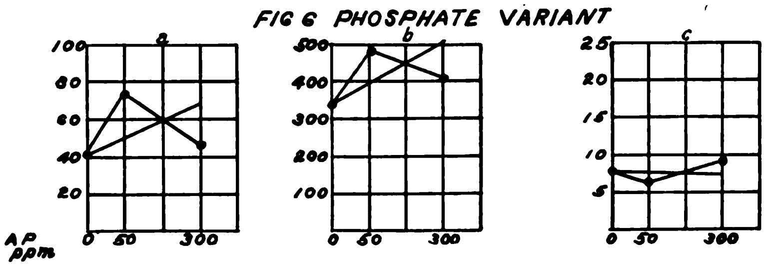



FIG 7 LIME VARIANT
AP 100 ppm
$NaNO_3$ 100 ppm
$K_2SO_4$ 100 ppm

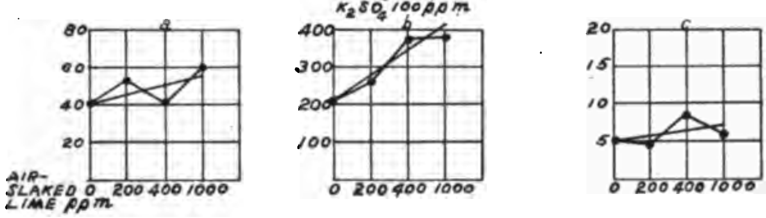



FIG 8 LIME VARIANT

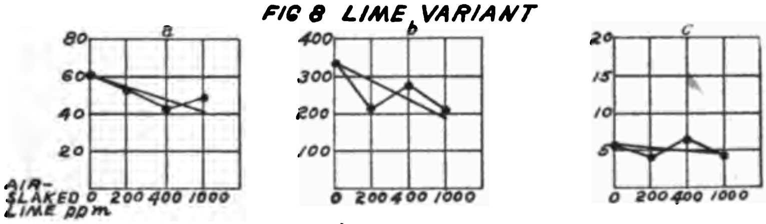


FIG 9 LIME VARIANT
AP 100 ppm
$K_2SO_4$ 100 ppm
$NaNO_3$ 100 ppm

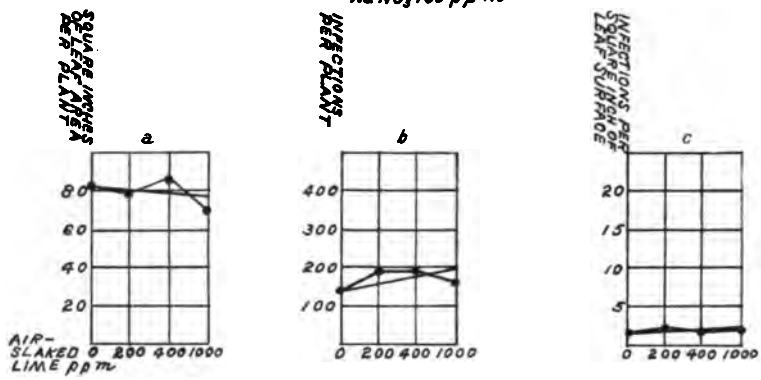



FIG 10 LIME VARIANT

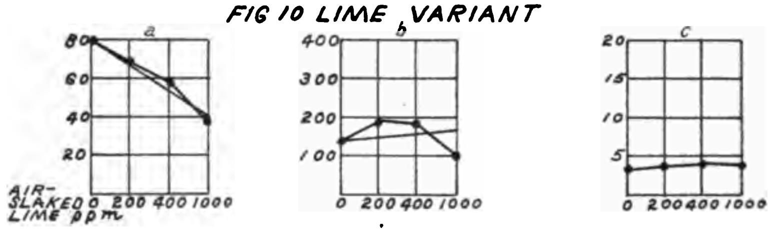



FIG 11 LIME VARIANT
AP 100 ppm
$K_2SO_4$ 100 ppm
$NaNO_3$ 100 ppm

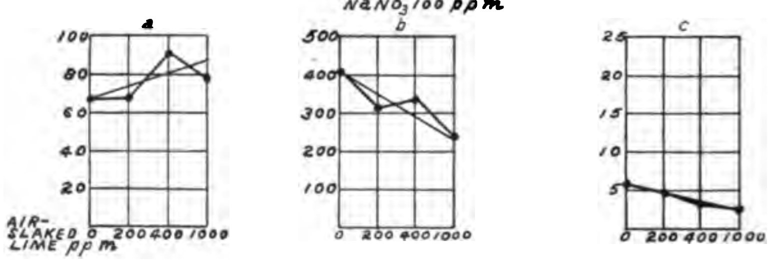



FIG 12 LIME VARIANT

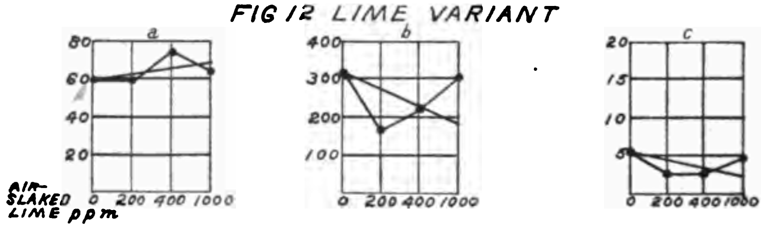


FIG 13 POTASH VARIANT
AP 100 ppm
$NaNO_3$ 100 ppm

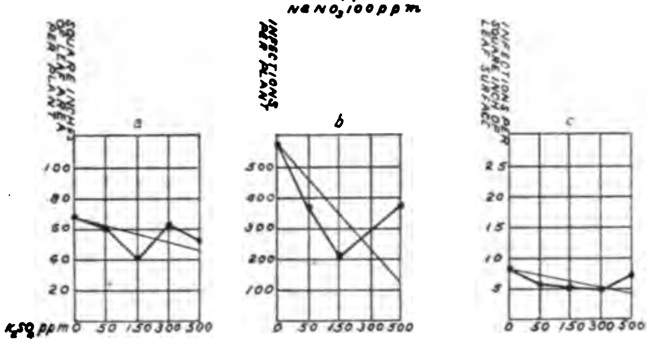



FIG 14 POTASH VARIANT

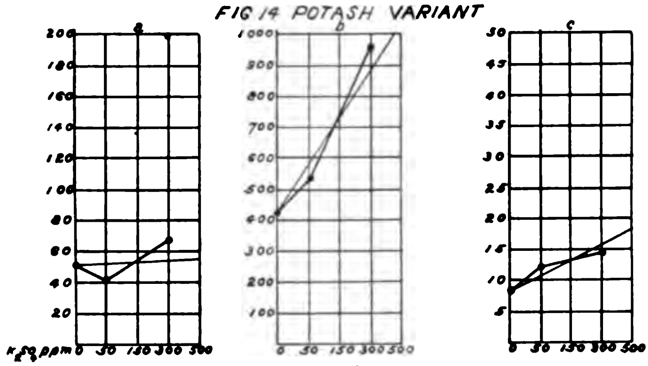



FIG 15 COPPER SULPHATE VARIANT
AP 100 ppm
$K_2SO_4$ 100 ppm
$NaNO_3$ 100 ppm

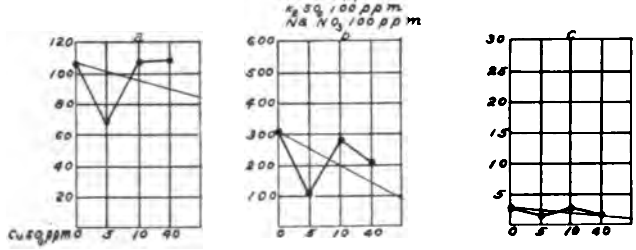
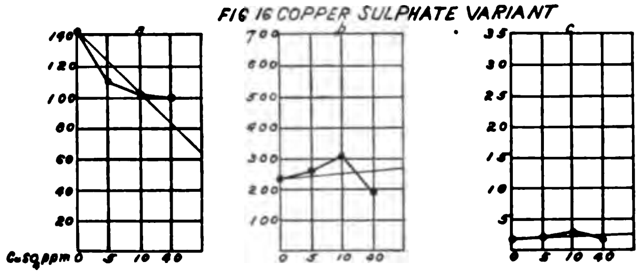



FIG 16 COPPER SULPHATE VARIANT



# THE RELATION OF AIR TEMPERATURE TO CERTAIN PLANT DISEASES

JAMES JOHNSON[1]

WITH PLATES XXI TO XXIII AND TWO FIGURES IN THE TEXT

That atmospheric conditions play an important rôle in determining the occurrence and severity of plant diseases is too well known to warrant introductory remarks in a brief paper. It is a striking fact, however, that a decided difference of opinion exists as to the most favorable conditions for the development of many of our best known diseases. This is due in large part to published opinions based on more or less limited observation. The need for more exact experimental data on this subject is becoming increasingly evident. The difficulties encountered in attempts at controlling air conditions in the presence of sunlight are, of course, the main reasons for the limited progress made in this direction.

The need for controlled air conditions became so great in connection with the writer's problems that in 1919 he undertook the construction of air-conditioning apparatus without, perhaps, fully understanding the inevitable barriers which lay ahead. By "cut and try" methods, however, an apparatus was finally developed in the fall of 1920 which has given controlled conditions quite satisfactory for present needs. It is not the aim of the present paper to describe this apparatus in detail, or to present a finished piece of research conducted with it, but rather to indicate the needs and possibilities for similar lines of work. A brief description of the chambers is essential, however, in order that the method may be understood and the reliability of the results obtained may be judged. Primarily for purposes of illustration three distinct types of diseases have been given most attention. These are: the mosaic disease of tobacco, the cause of which is as yet uncertain: the "wildfire" disease of tobacco, a bacterial leaf spot caused by *B. tabacum* Wolf and Foster; and the late blight of the potato, a fungus disease caused by *Phytophthora infestans*. Several other diseases have also been worked with, including tomato wilt caused by *B. solanaceranum* Erw. F. S. and an unnamed bacterial leaf spot of tobacco.

[1] Coöperative investigations of the Office of Tobacco Investigations, Bureau of Plant Industry, United States Department of Agriculture, and the Wisconsin Agricultural Experiment Station. Published with the permission of the Director of the Wisconsin Agricultural Experiment Station and the Secretary of Agriculture of the United States.

It is not proposed to review the literature bearing upon the subject of atmospheric conditions in relation to plant diseases, since this would be too voluminous. Brief reference will be made only to certain papers bearing directly on the subject.

## DESCRIPTION OF AIR-CONTROL CHAMBERS

The experiments to be described were conducted in three simultaneously operated chambers located in a greenhouse unit at the Wisconsin Agricultural Experiment Station. This greenhouse was heated with steam and fitted with thermostatic control and while ordinarily the temperature variation was about 5°, the range at times ran as high as 15° F.

The chambers fitted with air-control are composed essentially of five parts: the chambers proper, with due consideration for adequate insulation and light; an electric heater system in each chamber under thermostatic control; refrigeration within the cooler chambers; an automatically controlled humidifying system for each chamber; and means for renewal and circulation of air within the chambers.

*Construction of chambers.* The chambers are four foot cubes with three sides and bottom of wood and the top and one side of glass (Pl. XXI, fig. 1). Illumination was sacrificed in order to control more readily the air condition; but, as will be shown, the plants did not suffer esriously from lack of light during the period of exposure in the chambers, which was usually two weeks. Experience has shown that it is practically impossible to control the temperature in chambers constructed largely of glass exposed to full sunlight.

The bottom and three sides are of double walled ¾ inch cypress, with building paper and a dead air space between. The top and one side (the doors) are of two layers of single strength glass with air space between. The sides closed with glass also have wooden doors which can be closed for better insulation when light is not desired for certain types of experiments.

*Heating system.* The chambers are heated with 250 or 500 Watt Westinghouse heating units, regulated with Ostwald's toluene-mercury thermostats. The break of the heating circuit is therefore made by a relay operated through the thermostat by means of a direct current of two or three volts from storage batteries or from dry cells. The special feature introduced here is a double control system, that is, two thermostats, two relays (Pl. XXI, fig. 3) (connected in series) and two separate batteries for each chamber so that in case of accidental failure on the part of either the primary thermostat, relay or battery to operate, the secondary set would come into play following a small rise in temperature

This system obviated danger from overheating due to failure of apparatus to operate. A drop in temperature could result only from blowing out of fuses or burning out of the heating units.

*Refrigeration.* Artificial refrigeration was not available, and consequently ice had to be used. A small brine system was installed for one of the chambers, the primary coil (¾ inch) being in an ice chest holding about 500 pounds of crushed ice and the secondary coil being distributed over three inside walls of the chamber. Calcium chloride brine was circulated through the coils by means of a small rotary pump operated by a one-half horse power motor (Pl. XXI, fig. 2). The circulation of the brine was controlled by fitting the motor with thermostatic control. This gave fairly good results, although the variation in temperature was somewhat greater than in the heated chambers due to the "lag" of the cooling. The efficiency of the system was not more than 8–10° C below that of the greenhouse temperature, however, so that temperatures as low as 12 or 15° C could be maintained only during the winter months when the greenhouse temperature could be kept at or below 22° C.

In case of failure on the part of the brine system to operate, or when it was desired to save ice, a secondary cooling device could be brought into operation provided sufficiently cool weather existed out of doors. This consisted simply in blowing air from outside the greenhouse into the chamber by means of a blower (Pl. XXI, fig. 2, E) with thermostatic control. Excessive lowering of the temperature from refrigeration was guarded against by heaters connected with thermostats. It was also found necessary to introduce a small "check chamber" to prevent flow of cold air into the experimental chamber.

*Humidification.* The source of humidity consisted essentially of a current of air passing through a spray of water held at a temperature a few degrees above that of the chamber to be humidified. The water supply for all the chambers was heated by steam in a 40-gallon hot-water-tank fitted with a thermostat (Pl. XXI, fig. 4). By mixing the heated and cold water in a small "mixer" near the spray the proper temperature (as read by mercury thermometers set in oil wells in the mixers) of spray water could be secured for each chamber. The water passed through two screens before passing out through an ordinary mist type fruit tree spray nozzle. The spray was confined in galvanized iron tanks 5 feet high and 15 inches in diameter (Pl. XXI, fig. 3, J), with a drain at the base running into the sewer. Number O "Sirroco" blowers (1/20 H. P.) were used to blow air in at the base through the spray and out through a three inch pipe near the top, which led the current of warmed and saturated air into the chamber. The 110 volt current operating the blowers was connected through a relay, operated by direct current from

batteries through a "humidostat" in the chambers. This "humidostat" was simply a hygrograph with a platinum wire soldered to the pen arm so as to dip into a cup of mercury. When the relay circuit is completed through lowering of humidity, and resultant lowering of the wire into the mercury cup, the blower is operated until sufficient moist air is blown into the chamber to raise the pen arm and break the motor current circuit. At the same time the hygrograph pen draws the curve giving the humidity record. With proper adjustment quite constant humidity could be maintained in this way, the variation normally not being more than two or three percent (Fig. 1). This method can be worked satisfactorily only for high humidities. For running lower humidities it is planned to reverse the system; that is, pass the air through a spray of water colder than the chamber, thus reducing its moisture holding capacity before passing into the chambers. This method has not been tested sufficiently as yet to warrant statements in regard to its successful operation.[1]

*Renewal and circulation of air.* The renewal of the air is accomplished through the humidifying apparatus. Normally, fresh air is blown into the chamber every five or ten minutes. The circulation of the air within the chambers was accomplished by means of 13 inch fans running continuously in each chamber at a speed which kept the air in fairly rapid motion and absolutely prevented stratification. The fans were all operated by one motor (1/6 H. P.) (Pl. XXI, fig. 2, F) belted to the fan shafts. The speed of all the fans was therefore the same.

*Operation of the chambers.* Low growing plants were usually set on small tables in the chambers so as to bring them near the upper glass. Opening the doors to water the plants resulted in a rapid drop of humidity and of temperature which, though these were raised with almost equal rapidity when the doors were closed, usually resulted in disfigured curves. The plants therefore were set in large pans into which water was poured through a hose connected with a funnel on the outside, so that the plants were subirrigated, making it unnecessary ordinarily to open the doors more than once a week in order that the records might be changed.

The hygrographs and thermographs were relied upon only to show variation. The actual temperature readings were taken daily, and the humidity readings occasionally by means of a psychrometer set in front of a small electric fan which served to blow a strong current of air on the thermometers.

The evaporating power of the air was different, of course, at the different temperatures, even though the relative humidity might be the same in all cases. Three Livingston atmometers were used in each

[1] Since this paper was written a humidostat manufactured by the Johnson Service Company of Milwaukee has been used with good results.

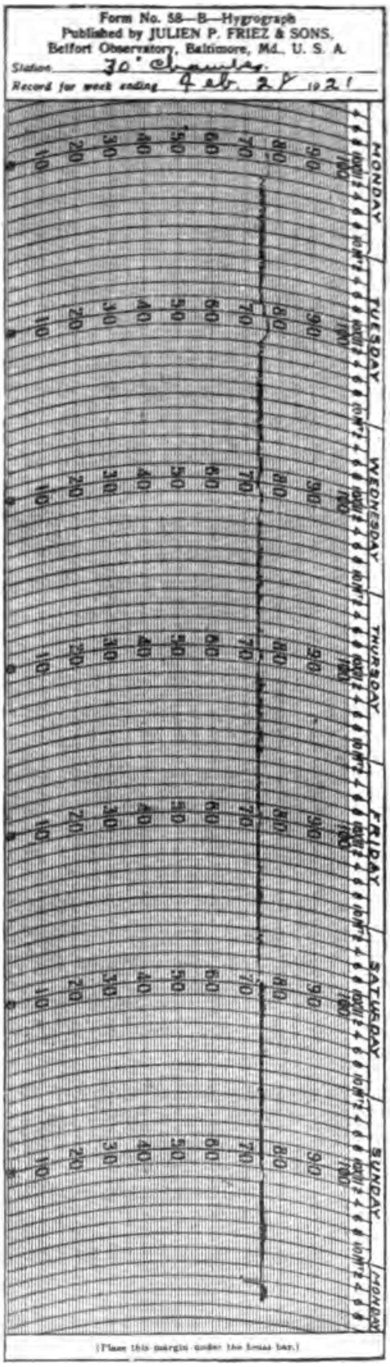



FIG. 1. HYGROGRAPH RECORD ILLUSTRATING THE DEGREE OF HUMIDITY CONTROL OBTAINED WITH GROWING PLANTS.

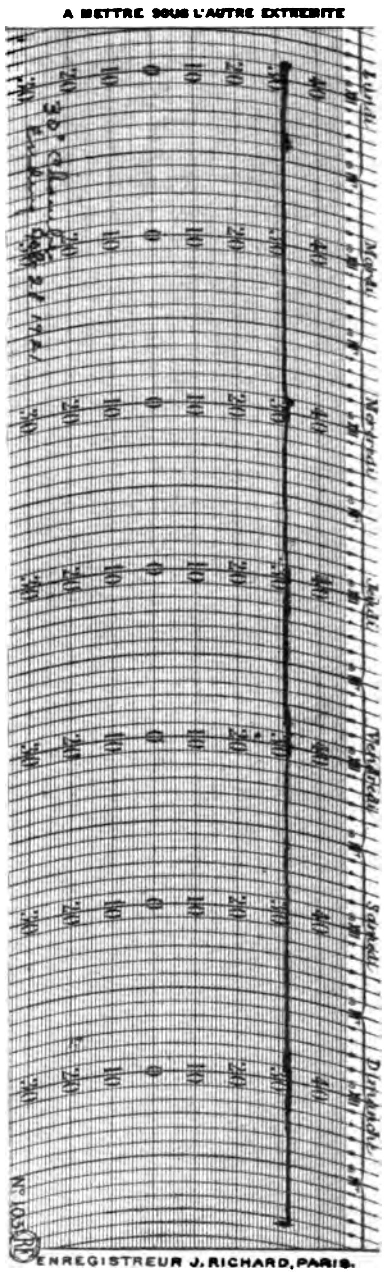



FIG. 2. THERMOGRAPH RECORD ILLUSTRATING THE TEMPERATURE CONTROL OBTAINED WITH GROWING PLANTS.

chamber to measure this factor. Time was not taken to secure adjustment for obtaining the same evaporating power in each chamber, but this was approximated in some instances, and was determined in all cases, so that its influence could be considered.

Two principal difficulties arise in operating the chambers. The first of these is condensation of moisture on the glass at high temperatures and high humidity. The second is the disturbing action of strong sunlight on the temperature of the chambers beginning with the spring months. Shading during part of the day was, therefore, necessary at times. These difficulties are not regarded, however, as having influenced the final results obtained in the experiments.

Since these chambers were completed the writer has had the opportunity of hearing discussions by Dr. Hottes of the University of Illinois on temperature and humidity control. A brief note has been published on his chambers (3). Parties interested in temperature and humidity apparatus construction should not fail to take advantage of Dr. Hottes' valuable ideas and long experience in this line before undertaking new construction.

## RELATION OF TEMPERATURE TO MOSAIC

Very little experimental data and only very limited observations exist with regard to the influence of temperature on mosaic. Doolittle (2) recently published a brief statement on the cucumber mosaic to the effect that . . . . "at soil temperatures between 22° and 27° C., the percentage of infection was the same, although the incubation period increased with lower temperatures. Increasing the soil temperature from 27° to 30° C., regardless of air temperature, reduced the incubation period from six to three days and produced a higher percentage of infection, accompanied by symptoms of a new type."

It is quite apparent that the development of mosaic symptoms is closely correlated with rate of growth in infected plants. Since soil temperature affects the rate of growth it is to be expected that it will also affect the incubation period for mosaic. The writer has undertaken, however, to study the effect of temperature upon the mosaic virus, itself, as measured by its rate of activity in the living plant, although to be sure we still cannot separate it completely from growth responses in the plant.

In studying the influence of temperature on the tobacco mosaic two methods have been used. In the first, the plants were inoculated and immediately placed in the chambers, where they were left for fourteen days, after which all were taken out and set on a greenhouse bench at one series of temperatures (usually a daily variation from 18–24° C.) where the progress of the disease was further observed. The second method consisted in placing plants already showing striking symptoms of the

disease in the chambers and observing its further development. The incubation period was longer in the short, dark days of the winter months than in February and March, owing apparently to a lower rate of growth. The results of six experiments are shown in table 1.

The data show a marked influence of air temperature on the incubation period for mosaic in tobacco. The absolute minimum possibly can never be determined since some host development must apparently occur in order to obtain the symptoms, and hence the incubation period could be theoretically lengthened indefinitely by holding the host at a temperature at which no growth is made. From this and other data the optimal temperature for the activity of the virus appears to be between 28 and 30° C and the maximal temperature is close to 36° C (Pl. XXI, fig. 1).

A significant condition arises when plants with all leaves already badly affected are placed at a temperature of 36–37° for about two weeks. The new leaves which develop are free from mosaic symptoms and most of the older leaves which are mottled but still in a growing condition gradually lose their mottled appearance and become apparently normal as far as symptoms go. This is due probably to the retarding of the deleterious action on chlorophyll production, nevertheless the virus is still present as shown by the reappearance of the symptoms when the plants are again subjected to lower temperatures. Apparently a similiar "recovery" of new leaves may be obtained by forcing a mosaic plant to grow by means of a favorable soil temperature in an air temperature considerably below the optimum for the virus, or by exposure of a mosaic plant to a constant temperature too low for good development of the disease but permitting some plant growth.

The experiments with mosaic were undertaken with the hope that some indirect evidence as to the nature of the casual agent might be established. Further experiments are planned to support the evidence secured in this direction. The general trend of the evidence however may be presented here. The correlation between the response of the mosaic virus with respect to temperature and that of living organisms is evident from table 1. Enzymatic action varies with temperature in a similiar manner, but the literature is uniformally agreed that the optimal temperature for enzymatic activity lies usually between 37° and 40° C, with the added assurance that their activity in the presence of their normal substrata is even higher. The influence of length of exposure to the temperature in question becomes an important factor to consider in this connection, however, and the effect of long exposure to comparatively low temperatures is as yet not adequately understood. If we assume that plant parasites are tissue destroyers through the activity of their respective enzymes we have evidence in these experiments that the

TABLE 1

*Influence of air temperature on mosaic of tobacco*

| EXPERIMENT NUMBER AND DATE | TEMPERATURE C° | RELATIVE HUMIDITY C. C. | AVERAGE DAILY EVAPORATION | NUMBER OF PLANTS INOCULATED | NUMBER OF PLANTS INFECTED AFTER (DAYS): IN CHAMBERS 8 | 10 | 12 | 14 | OUTSIDE CHAMBERS 18 | 22 | 26 | 30 | RELATIVE GROWTH AFTER 14 DAYS: AVERAGE NO. NEW LEAVES | AVERAGE INC. LGTH. LEAVES (CM.) | AVERAGE INCREASE OF HEIGHT (CM.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 12–15 | 69–81 | 8.1 | 5 | | | | 0 | 0 | | 0 | 5 | | | |
| 1–17–30 | 25–26 | 89–92 | 9.2 | 5 | | | | 1 | 5 | | 5 | 5 | | | |
| | 34–35 | 82–86 | 17.1 | 5 | | | | 0 | 0 | | 4 | 5 | | | |
| 6 | 13–15 | 60–90 | 9.2 | 7 | | | | 0 | 0 | 0 | 0 | 4 | | | |
| 2–1–13 | 25–26 | 79–83 | 9.4 | 7 | | | | 5 | 7 | 7 | 7 | 7 | | | |
| | 34–35 | 82–86 | 17.8 | 7 | | | | 0 | 0 | 5 | 7 | 7 | | | |
| 7* | 17–21 | 80–85 | 7.3 | 9 | 0 | 0 | 0 | 0 | 5 | 9 | 9 | 9 | 1.2 | 28.5 | 1.0 |
| 2–14–28 | 30–31 | 78–80 | 14.1 | 10 | 1 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 2.5 | 38.8 | 8.8 |
| | 35–37 | 82–89 | 14.9 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 1.7 | 34.4 | 10.0 |
| 8 | 27–29 | 80–85 | 12.4 | 10 | | 7 | 8 | 9 | 10 | | | | 3.6 | 74.7 | 7.7 |
| 2–28–3–14 | 30–31 | 77–82 | 19.2 | 10 | | 8 | 9 | 10 | 10 | | | | 3.2 | 61.9 | 10.1 |
| | 33–34 | 82–89 | 13.3 | 10 | | 1 | 6 | 8 | 10 | | | | 3.4 | 53.6 | 6.6 |
| 9 | 28–30 | 80–85 | 13.0 | 9 | 4 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 4.0 | 66.3 | 8.2 |
| 3–14–28 | 31–32 | 81–83 | 19.3 | 9 | 1 | 5 | 7 | 7 | 9 | 9 | 9 | 9 | 3.6 | 55.1 | 6.9 |
| | 35–37 | 82–85 | 14.4 | 9 | 0 | 3 | 3 | 3† | 3 | 5 | 6 | 7 | 3.6 | 48.9 | 6.4 |
| 10 | 18–22 | 70–80 | 12.5 | 10 | 0 | 0 | 0 | 0 | 7 | 9 | 10 | 10 | 3.5 | 56.2 | 4.0 |
| 3–28–4–10 | 29–30 | 88–90 | 7.8 | 10 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 4.8 | 78.5 | 11.8 |
| | 36–38 | 80–86 | 14.5 | 10 | 0 | 0 | 0 | 0 | 0 | 7 | 9 | 10 | 4.0 | 50.9 | 6.2 |

* Fuse blown out and temperature dropped proportionally in all chambers for about 12 hours on Feb. 17.

† Symptoms questionable and visible only by transmitted light.

enzyme or enzymes of *B. solanaceraum*, for instance, is at its height of activity at a temperature where the mosaic virus is no longer active (Pl. XXIII, fig. 2). Again, the metabolic processes in growing plants are now regarded as being dependent in a large part upon the activity of enzymes, and as may be seen from table 1, the growth activity of plants subjected to a temperature of 34–37° C. was not seriously affected as compared with the effect upon the mosaic virus.

Referring more specifically to the enzymes which are said by the supporters of the enzyme theory (1, 6) to be responsible for the mosaic disease of tobacco, namely, the oxidases principally, and, perhaps, the peroxidases and catalases, we can find only contradictory evidence in the temperature studies. If mosaic is due to the increased activity of these enzymes we should find them in greatest abundance at a temperature of 28–30° (in mosaic plants) but with their activity greatly reduced if not entirely eliminated in plants exposed for some time at a temperature of 36–37,° where the mosaic virus is no longer active as shown by the "recovery" of mosaic plants.

Qualitative and quantitative determinations of these enzymes do not indicate such reduced activity at the higher temperatures and consequently the part played by these enzymes as a causal agent in the mosaic disease is open to serious question. The increased activity of the oxidases in mosaic leaves seems to be therefore a result rather than a cause of the disease.

It is not to be expected that soil temperature in itself can directly affect the activity of the virus of mosaic. Since the appearance of mosaic symptoms is dependent very largely upon the rate of growth of the host, however, it follows that correlation between soil temperature and the mosaic symptoms will exist. Similarly, air temperature also must affect the incubation period for mosaic since it also influences the rate of growth of the host. With air temperature we have however the additional affect of temperature upon the activity of the virus. The determination of the relative importance of temperature on three different factors as influencing the symptoms of mosaic becomes very complex, particularly since the expression of each of these factors is dependent one upon the other.

Two experiments have been conducted to determine the influence of soil temperature upon the mosaic disease of tobacco. The first experiment was carried on in November and December 1920, with soil temperatures ranging from 15 to 35° C. Inoculations were made at three different times in the course of about six weeks with no symptoms occurring at any temperature, excepting finally at a soil temperature of 35° C. The plants at 25 and 30° became "frenched," however, which may have partially obscured the mosaic symptoms. The light condi-

tions were poor and the plants did not grow rapidly although they did increase their size two to four fold. The greenhouse temperature was purposely held low (below 20° C) to reduce the refrigeration necessary for the chambers with air control which were in the same house. It is now believed that the long incubation period in this experiment was largely due to the low air temperature prevailing.

In March 1921 another series of soil temperature tests was started under good light conditions and a relatively high air temperature (23 – 28°). The first symptoms were evidenced in 7 days at a soil temperature of 27–28,° followed on the eighth day by symptoms at 23–24° and at 30–32.° C. On the ninth day 100 per cent infection was found at soil temperatures of 27–28,° 31–32,° 34–36,° with 50 per cent at 23–24° and none at 19–20.° It seems reasonable to assume from these data and from the results in the chambers that the influence of soil temperature upon mosaic is largely a question of growth response in the host plant, that air temperature is of primary signficance, and that a soil temperature unfavorable for host development will increase the incubation period, even when an air temperature favorable for the host plant and the virus is maintained.

### THE "WILD-FIRE" LEAF-SPOT OF TOBACCO

Tobacco plants inoculated with the "wildfire" organism *Bacterium tabacum* Wolf and Foster were placed in the chambers simultaneously with the mosaic disease series. Infection was produced through needle pricks from a suspension of the organism in water. Infection without wounding has not proved uniform and reliable, consequently the above method was used. Three or four leaves on each plant were inoculated with 10 or 12 punctures on each leaf. The relative results are not readily expressed in per cent of infection (which was always 100 per cent unless below the minimum or above the maximum) or in size of lesions since the "halo" areas grade rather indefinitely into healthy areas. The data are therefore merely expressed in terms of relative amount of infection based on rapidity of infection and estimation of size of chlorotic ("halo") areas.

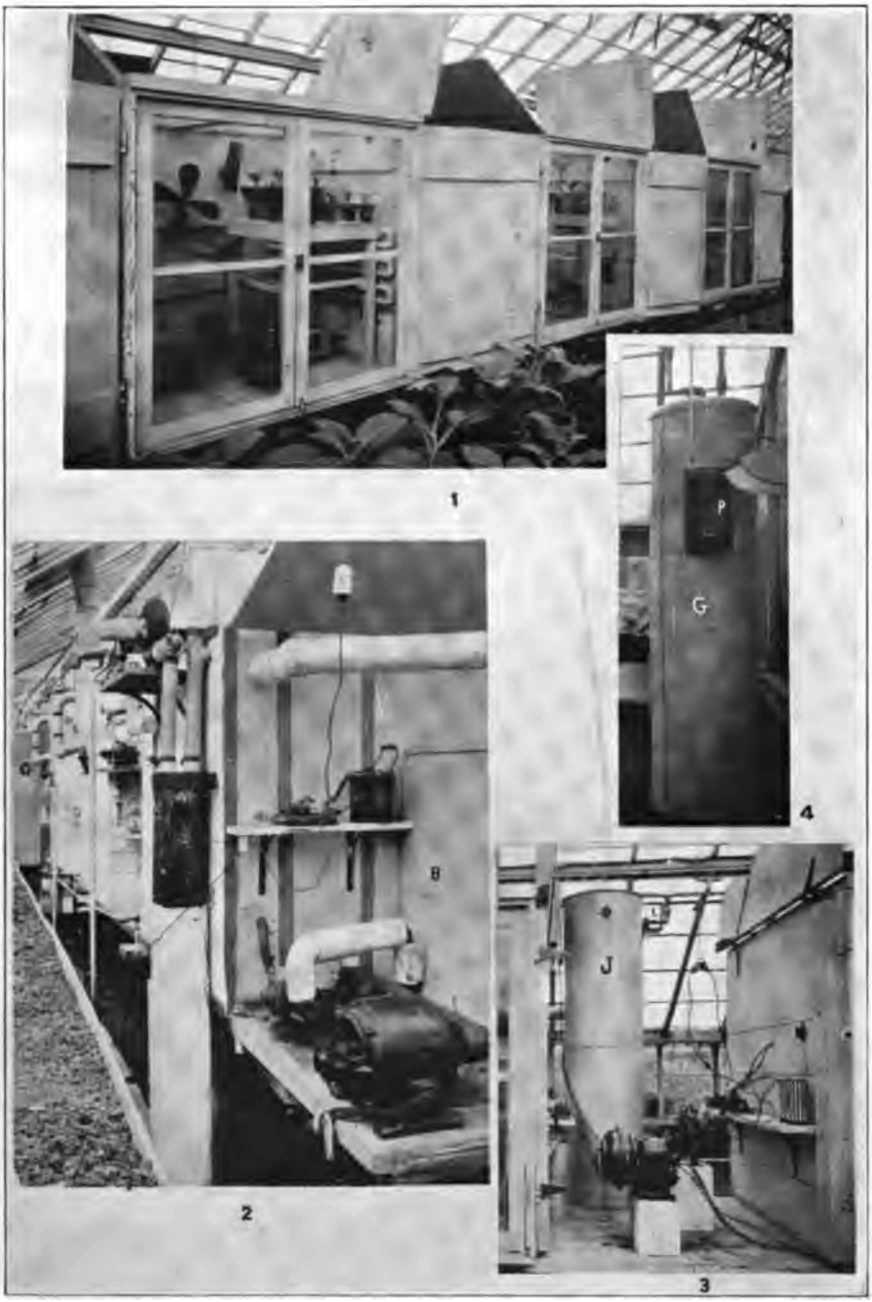
The evidence is quite conclusive that at the humidities prevailing and in wounded leaves the progress of the wildfire disease is very vigorous at a temperature as high as 34° C. (Pl. XXII, fig. 2), its maximum no doubt lying just beyond 37° C. The optimal temperature seemingly lies over a fairly wide range, 27–32° probably being sufficiently inclusive. Infection can occur and progress, on the other hand, at a relatively low temperature, the minimum being below 15.° Since the incubation period for this disease is very short, it is not surprising that it occurs in the early spring and in northerly tobacco sections; but, on the other hand, it will probably never be as serious in the northern as in the southern districts.

The maximum temperature for the growth of *Bacterium tabacum* in culture apparently lies close to 35° C. The optimal temperature could not be definitely established, but from cultures run in the controlled chambers and in other incubation chambers it apparently lies between 25 and 30°. At any rate the "wild-fire" organism seemingly is capable of attacking the tobacco leaf at a temperature at which it will not grow in culture on potato agar. These maxima lie fairly close together and it may be that the temperature of a respiring leaf is somewhat below that in a culture tube set in the same chamber.

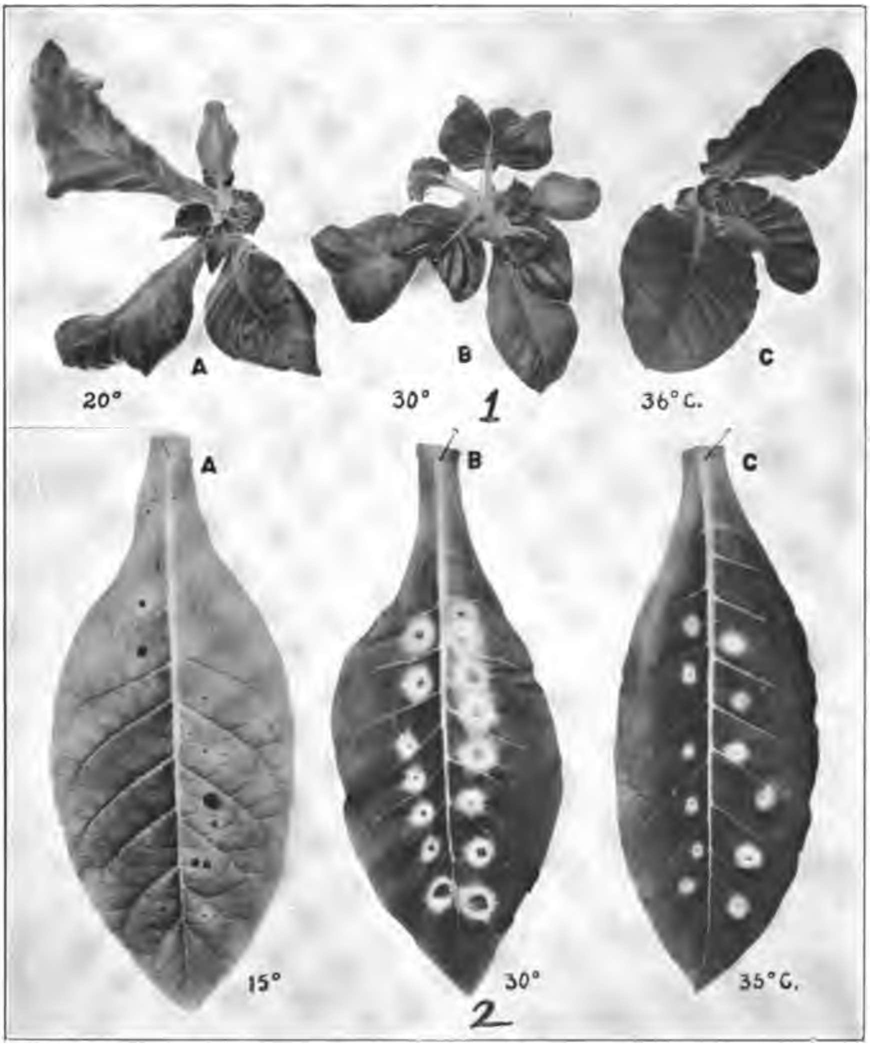
### THE LATE BLIGHT OF THE POTATO

The influence of environment on the Phytophthora disease of potatoes is of especial interest on account of the large volume of observational data which has been published concerning this disease. The literature seems to be fairly well divided in considering cold humid, and warm humid weather most favorable for the occurrence of the disease. The work of Melhus (5) has shown the importance of chilling in determing the amount of infection, although the development of the disease is said to be favored by higher temperatures. The writer's work upon this disease has not as yet been sufficiently extensive to warrant a detailed discussion of this subject, but it is hoped that at a later date, adequate consideration may be given to it. In the experiments thus far conducted the plants were usually inoculated and allowed to remain outside the chambers until signs of infection occurred. They were then placed in the chambers at the different temperatures. Seven series of experiments were conducted but good infection was secured in only five of the series. The results indicate that the progress of the disease below 25° C. is insignificant as compared with that at higher temperatures. The optimum appears to be between 25 and 32° and maximum above 36° C. (Pl. XXIII, fig. 1.). The most important fact brought out in these tests in view of the opinions expressed in relatively recent literature is that Phytophthora is a relatively vigorous parasite at temperatures as high as 32–35° C. The action of the fungus on the host corresponds quite closely with its growth in culture in the same temperature chambers, although again the fungus appears to be relatively more active on the host plant than in the culture tube. According to Jones, Lutman and Giddings (4) growth did not occur on Lima bean agar at 30° C. In my tests appreciable growth was secured on potato agar at 35–36° C.

The results are believed sufficient at least to justify the conclusion that the late blight of potato is favored by relatively warm, humid weather rather than by cool, humid weather as far as the development of the disease is concerned, although original infection, at least by



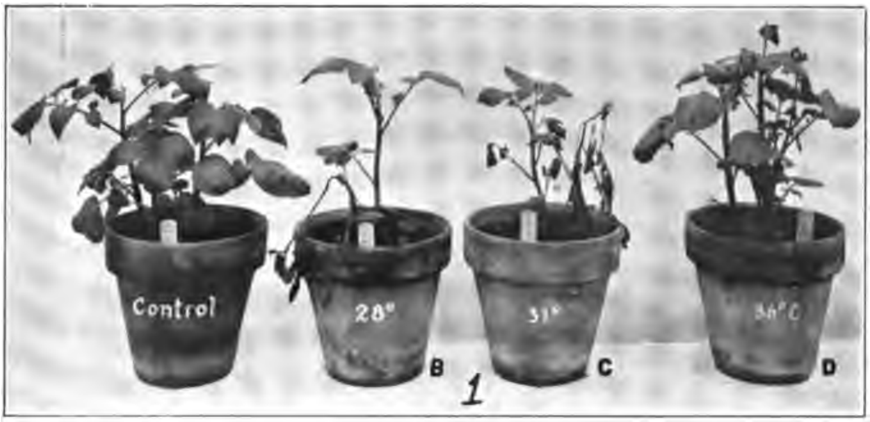

TEMPERATURE AND HUMIDITY REGULATING APPARATUS

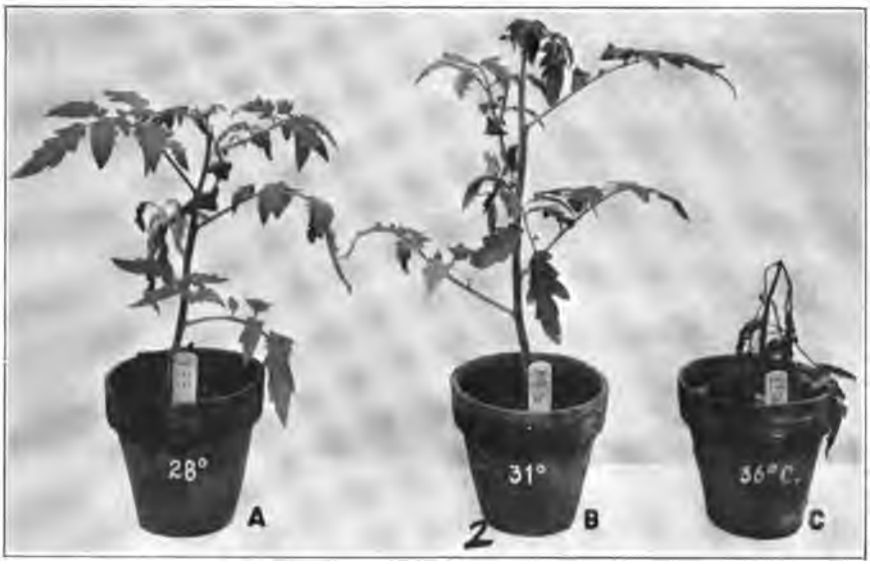



TOBACCO MOSAIC AND WILD FIRE GROWN IN CONTROLLED CULTURE CHAMBERS

FIG. 1. Illustrating the influence of air temperature on mosaic of tobacco. A. Inoculated and grown at 20° C. for 14 days. B. Inoculated and grown at 30° C. for 14 days. C. Inoculated and grown at 36° C. for 14 days. The plants were then exposed for an additional 14 days to ordinary greenhouse temperature (18–24° C.) with the plant exposed to 36° C. remaining free from mosaic symptoms.

FIG. 2. Showing the influence of air temperature on the "wild fire" disease of tobacco. A. Inoculated leaf from plant held at 15° C. B. Inoculated leaf from plant held at 30° C. C. Inoculated leaf from plant held at 35° C.




POTATO AND TOMATO WILT GROWN IN CONTROLLED CULTURE CHAMBERS

FIG. 1. The influence of air-temperature on the late blight of the potato. A. Inoculated with Phytophora and held under similar conditions to B, C, and D, until signs of infection occurred. A was then left under the ordinary greenhouse conditions and, B. Kept at 28° C. for four days. C. Kept at 31° C. for four days. D. Kept at 36° C. for four days.

FIG. 2. The influence of air temperature on the bacterial wilt of tomato (*B. solanacearum*). A. Inoculated and kept at 28° C. for five days. B. Inoculated and kept at 31° C. for five days. C. Inoculated and kept at 36° C. for five days. Some infection may be noted in A and B.

zoospores is undoubtedly favored by low temperatures as shown by Melhus (5). Consequently late potato blight should be most severe according to these studies, when the above named conditions follow each other in the proper order and persist the proper interval of time.


## SUMMARY

1. A series of chambers is briefly described in which the air-temperature and humidity are controlled within relatively narrow limits, while the growth of green plants is permitted.

2. A study has been made of the influence of air-temperature upon the mosaic disease of tobacco, a bacterial leaf-spot of tobacco (*Bacterium tabacum*) and upon the late blight of potato (*Phytophthora infestans*).

3. The optimal temperature for the development of mosaic lies between 28–30° C., and the maximal temperature at about 36–37° C. Mosaic plants placed at 36–37° send out new leaves, showing no symptoms of disease, and chlorotic leaves may recover their normal color. The temperature curve of this activity of the mosaic virus corresponds more closely to that of plant pathogenic organisms than to that of enzymatic or chemical action.

4. The activity of the enzymes, to which mosaic has been attributed, does not appear to be lowered at the maximal temperatures for the development of the disease and these enzymes are believed therefore to be an effect rather than a cause of the mosaic disease.

5. The optimal temperature for the "wildfire" disease of tobacco lies between 28–32°; the minimum is below 15; and the maximum above 37° C.

6. The optimal temperature for the development of the Phytophthora blight of potato lies above 25° and below about 32,° and probably quite close to the latter. The maximum lies close to 36–37° C. These results are believed to have some bearing upon the explanation of the occurrence and severity of the late potato blight disease.



THE WISCONSIN AGRICULTURAL EXPERIMENT STATION

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UNITED STATES DEPARTMENT OF AGRICULTURE


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PLATE XXI. APPARATUS TO REGULATE TEMPERATURE AND HUMIDITY IN CULTURE CHAMBERS

FIG. 1.—General view of front of air-control chambers. The chamber to the right shows the brine pipes, the table on which most of the plants were grown, and the fan used for air circulation.

FIG. 2. Rear view of the air-control chambers. A. Motor used to operate the brine pump. B. Ice box in which the primary brine coils are cooled. C. Relay operating the brine pump motor through thermostat. D. Check to prevent flow of air from chamber to the outside of the greenhouse or vice versa through the blower (E). E. Blower for cooling by drawing air from outside the greenhouse during cold weather, supplementing the brine system. F. Motor operating the fans in the chambers. G. Thermostated hot-water tank for heating the spray. H. Drain from "spray-tanks."

FIG. 3. Humidifying apparatus. I. Blower used for forcing air through spray in tank (J) into chamber. J. "Spray-tank" in which the spray is confined. K. One of the two relays used in the "double-control" of temperature. L. Hot and cold water pipes running into "mixer."

FIG. 4.—G. Hot-water tank, heated with steam. P. Thermostat controlling the temperature of the water in the tank.

# THE LIFE OF PUCCINIA MALVACEARUM MONT. WITHIN THE HOST PLANT AND ON ITS SURFACE

JAKOB ERIKSSON

Since the year 1912 I have made extensive investigations upon the life history of the hollyhock rust, *Puccinia malvacearum*. From the detailed report on the results of these studies, entitled "Das Leben des Malvenrostpilzes in und auf der Nährpflanze" which will be published soon (Kgl. Sv. Vet. Akad. Handl. Stockholm), I give some short extracts.

## I. DISEASED AND SOUND HOLLYHOCK RACES

In the year 1913 I cultivated in the experiment garden at Experimentalfältet (Stockholm) two different hollyhock races of differing origin. All plants were grown from seeds in June, 1912. The one race grew from September 1 to October 30, severely affected by the rust. The other race kept quite sound during the same period. The plants hibernated out of doors, covered with leaves and hatches.

On May 2, 1913, 32 plants of the diseased race were planted in 8 zinc cylinders, 1.3 meters deep and 0.62 meters wide, open at the bottom, embedded in the ground and filled with fertile soil. On the same day 32 plants of the sound race were planted in 8 cement boxes, 1 meter square, also buried in the ground and filled with fertile soil. The distance between the two cultures was from 10 to 15 meters.

All vessels were watered from time to time. From June 3 to August 23—June 3, 9, 18, 27, July 4, 25, 29, 30, August 8, 23—every leaf of every plant was carefully examined. The degrees of rust were indicated as follows: 1 = 1 to 10 sori, 2 = 10 to 25, 3 = 25 to 100 and 4 = more than 100 sori.

In table 1, I have assembled the results from 2 cylinders (8 plants) of the affected race and from 2 boxes (8 plants) of the sound race.

From this table we can learn two things: 1. There are two different periods of disease, caused by this fungus: the first period from the beginning of May to the end of July and the second from the end of July to the beginning of cold weather. During the first period the attack is slight, but during the second very bad. 2. The sound race of plants, in spite of the short distance between the two cultures, grew quite clean up to the last week of July. In 2 or 3 days (July 26 to 28) suddenly there appeared as at one blow an extreme outbreak of rust sori on all full grown leaves of all plants on sound as well as on affected races.

In the several years the sanitary state of hollyhock races, which had been experimented with, changed essentially. This may be seen in table 2.

According to this table, I worked during the years 1912–1916 with 7 races which I characterize as "affected originally and finally," and with 2 races (1913 and 1914), characterized as "originally sound, but during the spring and the summer of the second year infected from the diseased plants of the other race," growing close to them. In the years 1917 to 1920 I worked with 4 races sound from the beginning to the end of the culture, with 1 (or 2) races (1919), affected the whole time, and with 2 races (1918 and 1920), which changed from affected to sound.

TABLE 1

*Hollyhock rust at Experimentalfältet (Stockholm) in the year 1913*

| DAYS | RACE AFFECTED 2 CYLINDERS—8 PLANTS | | | | | LEAVES DEAD | TOTAL | RACE SOUND 2 BOXES—8 PLANTS | | | | | LEAVES DEAD | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NUMBER OF LEAVES WITH DEGREE OF RUST | | | | | | | NUMBER OF LEAVES WITH DEGREE OF RUST | | | | | | |
| | 0 | 1 | 2 | 3 | 4 | | | 0 | 1 | 2 | 3 | 4 | | |
| 3-6 | 61 | 1 | 1 | | | | 63 | All leaves clean | | | | | | |
| 9-6 | 45 | 15 | 2 | 1 | | | 63 | " | " | " | | | | |
| 18-6 | 30 | 8 | 14 | 8 | 1 | 2 | 63 | " | " | " | | | | |
| 27-6 | 21 | 6 | 8 | 21 | 2 | 5 | 63 | " | " | " | | | | |
| 4-7 | 21 | 5 | 3 | 21 | 6 | 7 | 63 | " | " | " | | | | |
| 25-7 | 12 | 16 | 8 | 24 | 12 | 33 | 105 | " | " | " | | | | |
| 29-7 | 13 | 18 | 13 | 17 | 54 | 36 | 151 | | | | | | | |
| 30-7 | | | | | | | | 28 | 15 | 13 | 18 | 61 | | 135 |
| 8-8 | | | | | | | | 30 | 15 | 13 | 15 | 61 | | 134 |
| 23-8 | 35 | 22 | 27 | 10 | | 74 | 169 | 13 | 11 | 14 | 25 | 69 | 36 | 168 |

Further, it is to be remarked that the summer stage of the disease quite or partially failed to appear in the years 1915 to 1920. Nevertheless the disease appeared in the autumn stage in the years 1915, 1916 and 1919 on the young plants of the first year as well as on the old plants of the second year.

## II. WATERING OF THE CULTURE SOIL WITH FUNGICIDES

In the year 1913, I also made some experiments of watering certain plants with a diluted solution of copper sulphate. The results of these experiments are to be found in table 3.

From this table, we can conclude that copper sulphate is an effective means to stop the life energy of the fungus during the summer period of the disease, from the earliest spring to the last week of July, but

that it is without any effect whatever during the autumn period of disease, from the end of July to the beginning of winter. The most favorable concentration of the copper solution seems to be 0.3 per cent.

Upon the sound race of plants no effect of the watering with the fungicide was to be detected either in the first or in the second period

TABLE 2

*Sanitary state of hollyhock races in 1912–1920*

(Bergianum = Bergian Garden (Stockholm); Haga = Haga Garden (Stockholm); Hilleshög (Skåne); Västeras (Västmanland).

| YEARS | ORIGIN | FIRST YEAR | SECOND YEAR | | | RACE LIKELY | |
|---|---|---|---|---|---|---|---|
| | | AUTUMNAL OUT-BREAK (PROLEPTIC) | CLEAN PERRIOD | FIRST RUST PERIOD (SUMMER STAGE) | SECOND RUST PEIOD (AUTUMNAL STAGE) | ORIGIN-ALLY | FINALLY |
| 1912 | Haga | bad 15/8–15/9 | 3/5–18/6 | bad 26/6–15/7 | bad 31/7–17/8 | affected | affected |
| 1913 | Haga | bad 1/9–30/10 | 2/5–24/5 | bad 24/5–4/7 | bad 25/7–23/8 | affected | affected |
| | Bergianum | O | 3/6–25/7 | O | bad 28/7–22/8 | sound | affected |
| 1914 | Haga | bad | O | bad 1/5–25/7 | bad 27/7– | affected | affected |
| | Bergianum | O | 2/5–8/5 | slight 9/5–25/7 | bad 27/7– | sound | affected |
| 1915 | Hilleshög | slight 3/10–10/11 | 20/5–10/7 | O | bad 16/7–6/9 | affected | affected |
| | Haga | very slight 15/10–3/11 | 20/5–10/7 | O | bad 16/7–6/9 | affected | affected |
| 1916 | Bergianum | very bad 9/9–3/10 | Ser. A 17/5–12/7 | O | bad 19/7–9/8 | affected | affected |
| | Bergianum | very bad 9/9–3/10 | Ser. B-D O | slight 17/5–12/7 | bad 19/7–9/8 | affected | affected |
| 1917 | Bergianum | ? | 24/5–23/8 | O | O | sound | sound |
| 1918 | Bergianum | very bad 2/11 | 6/5–20/8 | O | O | affected | sound |
| 1919 | Västeras | ? | 23/5–15/9 | O | slight 4/8–15/9 | | affected |
| | Haga | very slight | 19/5–15/9 | O | bad 4/8–15/9 | affected | affected |
| | Bergianum | O | 19/5–15/9 | O | O | sound | sound |
| 1920 | Bergianum | very bad 2/19–18/10 | 15/5–23/8 | O | O | affected | sound |
| | Västeras | O(?) | 15/5–23/8 | O | O | sound | sound |
| | Haga | O(?) | 15/5–23/8 | O | O | sound | sound |

of the disease. The great difference in the effects of the watering with the fungicide in the different periods of disease shows evidently that this fungus must live in the tissues of the host plant in another mode of existence during the spring and summer (May–July) than during the autumn (August–October).

The fact that a fungicide added to the water used for watering the culture soil can restrain the fungus element in the symbiose, without damaging the normal element of the host cell itself, must be regarded as the introduction of a new method of combatting the diseases of plants, i. e., a method of internal therapeutics.

TABLE 3

*Watering experiments in the year 1913, each series is represented by 8 plants in 2 cylinders.*

| DAYS | SER. A: WATER — NUMBER OF LEAVES WITH DEGREE OF RUST 0 | 1 | 2 | 3 | 4 | LEAVES DEAD | TOTAL | SER. B: 1% COPPER SULPHATE — NUMBER OF LEAVES WITH DEGREE OF RUST 0 | 1 | 2 | 3 | 4 | LEAVES DEAD | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| June 3 | 61 | 1 | 1 | | | | 63 | 55 | 8 | | | | | 63 |
| " 9 | 45 | 15 | 2 | 1 | | | 63 | 46 | 13 | 2 | 2 | | | 63 |
| " 18 | 30 | 8 | 14 | 8 | 1 | 2 | 63 | 38 | 17 | 4 | 2 | | 2 | 63 |
| " 27 | 21 | 6 | 8 | 21 | 2 | 5 | 63 | 37 | 15 | 4 | 2 | | 5 | 63 |
| July 4 | 21 | 5 | 3 | 21 | 6 | 7 | 63 | 43 | 7 | | | | 13 | 63 |
| 25 | 12 | 16 | 8 | 24 | 12 | 33 | 105 | 44 | 9 | | | | 30 | 83 |
| 29 | 13 | 18 | 13 | 17 | 54 | 36 | 151 | 19 | 16 | 14 | 16 | 36 | 32 | 133 |
| Aug. 23 | 35 | 22 | 27 | 10 | | 74 | 168 | 49 | 26 | 22 | 6 | | 62 | 165 |

| DAYS | SER. C: 0.3% COPPER SULPHATE — NUMBER OF LEAVES WITH DEGREE OF RUST 0 | 1 | 2 | 3 | 4 | LEAVES DEAD | TOTAL | SER. D: 0.2% COPPER SULPHATE — NUMBER OF LEAVES WITH DEGREE OF RUST 0 | 1 | 2 | 3 | 4 | LEAVES DEAD | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| June 3 | 59 | 3 | | | | | 62 | 63 | 3 | | | | | 66 |
| " 9 | 48 | 13 | 1 | | | | 62 | 45 | 18 | 2 | 2 | | | 67 |
| " 18 | 47 | 10 | 2 | | | 3 | 62 | 49 | 12 | 3 | 1 | | 3 | 68 |
| " 27 | 45 | 12 | 1 | | | 7 | 65 | 45 | 9 | 2 | 1 | | 12 | 69 |
| July 4 | 54 | 4 | | | | 7 | 65 | 48 | 5 | | | | 16 | 69 |
| " 25 | 53 | 26 | | | | 21 | 100 | 52 | 26 | 3 | | | 35 | 116 |
| " 29 | 33 | 29 | 18 | 19 | 13 | 25 | 137 | 36 | 24 | 15 | 24 | 25 | 44 | 168 |
| Aug. 23 | 60 | 16 | 19 | 7 | | 13 | 155 | 58 | 13 | 15 | 19 | | 69 | 174 |

## III. GERMINATION OF THE SPORES

All spores of this fungus are two-celled and morphologically equal, but in reality we have to distinguish between two biologically different forms of these spores, different in the manner of germination as well as in their method of producing infection.

The one spore form is that of the autumn spores, which occur on the young plants of the first year and on the old plants of the second year, in the months of August until October. These spores are able to germinate in two different manners. If these spores lie on the surface of a drop of water or in moist air they germinate with short and curved basidia (promycelia), which are generally divided into 4 segments. From the side of each one of these segments a basidiospore (sporidium) is separated. If these autumn spores lie submerged in water they germinate with long and straight tubes, which at the tip liberate bud-cells (conidia), arranged like a string of beads. The other form of spores is the summer spores, which occur on the hibernated plants of the second year, in the months of May until July. These spores whether lying upon or under water germinate only in one manner, with long and straight tubes which liberate conidia.

In some cases the mycelium of the autumn generation survives in the tissues of the host plant from the first year to the second year and during the spring and the summer continues in developing autumn spores which germinate in the two ways above mentioned, short as well as long. That occurred in my experiments (Bergianum) in the year 1914, and to a certain extent also in the year 1916. In other cases the summer spores failed to appear at all. That occurred in my cultures (Bergianum) in the years 1915, 1917, 1919 and 1920. In yet other cases only the summer-spore stage is developed and this stage kills all the leaves of the plants already in July. That occurred (Malmö, South Sweden) in the year 1920 on old hollyhock plants and on new plants of *Malva silvestris*.

The two spore-forms are different also in another regard: on reaching a leaf of a plant susceptible to the fungus, the sporidium penetrates the epidermis by means of a germ tube and produces after 8 to 10 days new rust sori on its surface. On the contrary on reaching such a leaf the conidium infuses its contents as plasm in the epidermal cell, the nucleus of this cell becomes hypertrophied and the plasm penetrates into the interior of the leaf to constitute a mycoplasm. In this case no new sori are developed on the infected leaf; only sharp, limited, dead spots, finally white, or none at all, appear on those places, where the inoculum had been placed.

By proving that there are two different forms of spores, different in regard to their germination and to their infecting power, the surprising phenomena of the year 1913—a race of hollyhocks sound in the months of May until the end of July, growing side by side with an affected race—have now cleared up, as well as many heretofore inexplicable, often contradictory statements of observations in the older as well as in the modern professional literature.

STOCKHOLM.

# EUROPEAN CANKER ON THE PACIFIC SLOPE

S. M. Zeller and C. E. Owens

With Four Figures in the Text

Since January, 1918, when Professor H. P. Barss identified the European canker on the Red Cheek Pippin apple in Marion County, Oregon, specimens of this trouble have been received by the Department of Botany and Plant Pathology, of Oregon Agricultural College, from various localities in Oregon and one in California. It has been reported from four points in Marion County, one in Hood River, one in Clatsop, one in Tillamook, eight in Benton, one in Linn, one in Lane and one in Douglas County. Other suspicious cankers have been observed in Hood River and Wasco Counties but since no fruiting stages were in evidence positive identifications were not made at the time of collection. In April, 1920, we received a specimen of European canker on apple from Humboldt County, California, sent in by Professor Elizabeth H. Smith, University of California.

Among the specimens which have been identified as due to *Nectria galligena* Bres. were several cankers on apple the varieties of which were unknown to us. The hosts for this canker upon which the perfect stage (*Nectria galligena*) or the imperfect stage (*Fusarium Willkommi* Lindau) have been definitely determined for the region under consideration are several apple varieties, namely, Red Cheek Pippin, Bismark, Delicious, Winter Bellflower, Spitzenburg, and Newtown and also D'Anjou, Howell and Bosc pears.

In Europe and the northeastern part of the United States the European canker on apple is described as a slow-growing disease which enters the host through some wound or bruise, usually where a small twig or spur has been broken or pruned off, where the strain on crotches has caused a crack, and through such bruises as may occur by the impact of hailstones upon the bark. It spreads slowly, killing the bark as it goes. Each year the bark at the periphery of the canker is encroached upon by the fungus and is killed, thus causing a new callus to form just outside of the last one. As the disease thus spreads over a period of years a number of concentric calluses are formed. The dead bark falls away exposing the wood so that these concentric wood calluses show up conspicuously, giving the entire canker its striking appearance, which is characteristic

of the open type of canker as it occurs there. This type of canker is reported as prevailing especially on erect, vigorous scaffold branches of the tree while a closed, rough gall-like canker is characteristic of the horizontal or hanging branches.

However, on the Pacific Slope the concentric arrangement of callus rings in old cankers is much less in evidence and usually can not be found in most cankers caused by *Nectria galligena*. For some reason, possibly due to climatic or other conditions not yet fully understood, the cankers spread very rapidly, sometimes extending for several inches or even one

FIG. 1. A CROTCH INFECTION ON D'ANJOU PEAR. THE CANKER HAS FOLLOWED WINTER INJURY IN THIS INSTANCE AND IS IN ITS SECOND YEAR.

or two feet in a single season and remain more or less closed. One can readily imagine that this continual lateral and longitudinal growth without callus formation can be possible only in a locality where there is a prolonged humid season with moderate temperature such as usually prevails for several months on the Pacific Slope of the Northwest. This perhaps is the reason that we find in western Oregon these large cankers covering many square inches of bark surface without the conspicuous formation of calluses.

For the most part there is every indication that infections take place at small, sappy, pruning cuts or in crotches. On the Red Cheek Pippin apple and Bosc and D'Anjou pear, cankers have been observed frequently to start in the crotches of the largest branches, as shown in figure 1. In many instances where there are no pruning cuts there are indications of infection in the crotches of fruiting and leaf spurs. Wherever the bark

FIG. 2 FIG. 3

FIG. 2. A TYPICAL ONE-YEAR-OLD CANKER ON BOSC PEAR. INFECTION STARTED AT A SMALL DEAD SPUR. NOTICE THE ROUGH, CLOSED TYPE OF CANKER

FIG. 3. A CLOSED CANKER ON THE RED CHEEK PIPPIN. THIS CANKER IS SEVERAL YEARS OLD

of the host has become devitalized, through sun scald or winter injury, for instance, the fungus obtains an easy access and from there spreads to the healthier tissues. In some cases it has been found that the fungus has obtained its start in the periphery of cankers produced by *Neofabraea*

*malicorticis* on D'Anjou pear. In an orchard of Bosc pears in Benton County where nearly every tree has some cankers of *Nectia galligena* there is considerable bark injury due to the freeze of December, 1919. From many of these winter-injured areas cankers produced by *Nectria galligena* are spreading with extreme vigor. In most cases of such winter injury both to Bosc and D'Anjou pear, *Nectria cinnabarina* (Tode) Fr. has also gained a foot-hold and there is much evidence that this fungus although usually saprophytic, exists as a parasite at least upon partially devitalized bark and wood.

Although the life history of *Nectria galligena* should be traced definitely for the humid conditions under which it is found here there are some observations which have already been made which we believe should be presented at this time. Near Corvallis the sappy, soft cankers upon which the macro- and microconidia occur have been observed on D'Anjou pear during the early part of June. For the most part these cankers occur around early-spring pruning cuts and unmistakably are due to infections of this spring. By the middle of June many of these cankers had already reached 20–22 inches in length and 1.5–2.5 inches in breadth. If the bark around such cankers is removed it will be found that in most cases the fungus has destroyed the cambium far beyond the superficial limits of the cankers. If the bark is cut through at the margin of the canker where the cambium is thus destroyed the bark will shrink away from the wood exposing a slimy wood surface, the limits of which are definite, making it possible to cut off the bark beyond the limits of this cambium infection, when disinfection and antiseptic methods are applied.

In contrast to the above-mentioned advance of the fungus in the cambium there seems to be a very different type of canker formed at times on pear bark, perhaps by another organism, in which there is no apparent damage to the bark deeper than the inner cortex. In these cases the cambium is apparently in perfect health and remains in this condition during the first season of the life of the canker. This type of canker has all the appearance of the early stages of European canker but we have never seen fruiting bodies of *Nectria galligena* in connection with it.

Upon cankers caused by *N. galligena* and which we suspect were formed the same season the senior author has found pustules of the multi-septate, sickle-shaped macroconidia as well as the ellipsoid, one- and two-celled microconidia. These were found on apple cankers collected February 3, 1920 and on pear cankers collected October 13 of the same year. The white stromatic cushions bearing these conidia are shown in figure 4. The microconidia and macroconidia to date have been found in

early spring and lasting at least until October. The stromatic cushions of conidia first appear very near the seat of infection and later break out as pustules further out from this point as the canker increases in size. Embedded in these stromatic pustules of conidiophores are to be found the early stages of perithecia the development of which will be described later by one of us.

In the very early stages of the canker, especially on pear, the bark becomes undulating, the raised portions having a spongy edematous character. Following this edematous condition the epidermis peels off irregularly giving a more or less shaggy appearance to the new oozy canker. The unbroken epidermis easily slips off upon pressure with the finger. The exposed portions of the cortex are then black and moist.

FIG. 4. CANKER ON D'ANJOU PEAR SHOWING THE WHITE STROMATIC PUSTULES OF THE FUSARIUM STAGE OF THE FUNGUS, NECTRIA GALLIGENA

As the cankers become older the killed bark becomes very much cracked and furrowed, sometimes along irregular lines, but many times especially where the disease made its first vigorous onslaught these cracks take on a more or less concentric arrangement although of course these concentric fissures do not represent annual growth periods as in the case with the open type of canker found in other localities, but may represent merely a periodicity of growth of the fungus due to changes in moisture or temperature during a single season. This is perhaps similar to the closed type of canker reported from other regions, but evidently is much more rapid in growth. Occasionally in this state cankers are found upon apple which for some reason (possibly host resistance) have developed more slowly and in such cases there may be a slight tendency toward an open concentric callus formation.

OREGON EXPERIMENT STATION,
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PHYTOPATHOLOGY

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# THE EFFECTS OF TREATMENT FOR BUNT ON THE GERMINATION OF WHEAT

George L. Zundel[1]

With Two Figures in the Text

## INTRODUCTION

Peculiar climatic and soil conditions are chiefly responsible for the severe smut losses in the state of Washington. In an attempt to control this smut (*Tilletia tritici*), commonly known as bunt or stinking smut, fully 99 per cent of all seed wheat planted in the state is treated by dipping in solutions of copper sulphate, copper sulphate and sodium chloride, or formaldehyde. When any seed is treated with toxic compounds, there is usually more or less injury to such seed, regardless of the care exercised. The treatment of wheat in either copper sulphate or formaldehyde is no exception to the rule. There are, however, peculiar climatic and soil factors, together with the method of threshing, which, in Washington, make seed injury a serious problem. Hot, dry weather is the usual condition at harvest time in Washington, causing the wheat kernels to be dry and brittle. When this wheat is threshed in our modern threshing machines, with high speed cylinders, many of the kernels are either broken, badly cracked, or otherwise injured. Most of the cracks are invisible to the eye, but when these kernels are dipped into fungicides they allow the fungicide to penetrate to the embryo, causing much injury.

## HISTORICAL

The harmful effects of fungicides have been studied by numerous investigators in various countries. In 1876, Pierre (35) found that seeds of wheat dipped in boiling milk of lime for two or three minutes were killed; 54 per cent germinated after being dipped in a 2 per cent solution of copper sulphate for three minutes at 60° C. and 53 per cent germinated when treated at 50° C.

Kudelka (23) reported in 1876 that wheat soaked in a ½ per cent copper sulphate solution for sixteen hours was only slightly injured. However, even a two hour soak produced a slight retardation of germination.

[1] Acknowledgment is due Dr. F. D. Heald of the State College of Washington for helpful suggestions in the preparation of this manuscript and for providing means for the carrying on of this work. Helpful criticisms of manuscript were also given by Dr. Harry B. Humphrey and Dr. C. R. Ball of the U. S. Department of Agriculture.

Maercker (27) found in 1887 that sulphuric acid lowered the germination of barley from 1 to 5 per cent according to the thickness of the seed coat.

In 1890 Crozier (8) found that wheat treated with copper sulphate germinated more slowly than when untreated. He observed also that injury increased with the length of the treatment.

Jones (19) found that seed corn was injured by hot water treatment over 130° F. for fifteen minutes, as did a 6¼ per cent copper sulphate solution for twenty-four hours. The injury varied with the quality of the seed lot.

Hitchcock and Carlton (15) tested the effects of various fungicides on the germination of seed corn. The results from a large number of tests with various chemicals show that the chemicals can be classified into three groups according to the amount of injury produced.

Evans (11) of the United States Department of Agriculture, in 1896, studied the injury of wheat by fungicides and found that even small openings in the seed coat over the embryo may lead to severe injury when the seed is dipped in a fungicide.

Bolley (2) in 1897 tested the injury to germination of wheat, oats and barley after treatment with copper sulphate, sulphur dioxide, corrosive sublimate, and formaldehyde. Copper sulphate injured the germination of oats as much as 92 per cent, and wheat as much as 43 per cent. Formaldehyde injured the germination of wheat and oats up to 23 per cent. Injury was also caused by the other chemicals.

Windisch (44) treated wheat, rye, barley, and oats in formaldehyde solutions ranging from .02 to .4 per cent, soaking the cereals for twenty-four hours. The weakest solution favored the germination of oats but injured the germination of the other cereals. The strongest solution killed all of the cereal seeds.

Kinzel (21) in 1898 treated cereals with very concentrated solutions of formaldehyde but used comparatively short durations of treatment (½ to 2 hours). Concentrations of 0.1 per cent or 0.2 per cent with a duration of treatment of from one-half hour to one hour did not injure the viability or retard germination of rye and wheat, but barley and oats were injured.

In 1899, David (9) found that the degree of injury by formaldehyde varied with the different cereals, and was in direct proportion to strength of the solution and duration of treatment. The seed injury was manifest in a retarded and abnormal germination in which no roots were produced. The injurious effects of formaldehyde were reduced by soaking for fifteen minutes in a weak solution of ammonia.

Schellenburg (38) in 1899, found that when the seed coat of cereals was cracked during the process of threshing that injury to germination from treatment with formaldehyde and copper sulphate was much increased compared to cereals that had been threshed with the flail. The threshing machine usually damaged the larger kernels.

Falke (12) in 1900, showed that dipping cereals in ammonia water after the formaldehyde treatment does not stop injury to germination. His experiments showed a decrease in germination when ammonia water was used.

In 1900, Pernot (33) found that hot air treatment has a wide range of temperature without injuring oats. Injury is more liable to occur by the use of the dipping methods due to the difficulty of drying the oats.

In 1900, the Wyoming (1) Agricultural Experiment Station found that soaking wheat in copper sulphate solution of one pound to 24 gallons of water for thirteen hours, then immersing in lime water for five minutes injured the seed. Injury resulted also where a 2 per cent solution of potassium sulphide or hot water at 135° C. for fifteen minutes were used. It was supposed that the wheat grown near Laramie, Wyoming, had much thinner seed coats than usual and thus allowed the fungicides to penetrate to the embryo.

Cranefield (6, 7) in 1901, and again in 1902, found much injury to the germination of oats treated with formaldehyde. Injury increased with the length of duration of treatment and his final conclusion was that injury increased in direct proportion to the strength of the solution.

In 1901, Demoussy (10) working in France, found that copper sulphate did not penetrate the seed coats of wheat. When the treated seeds were germinated on filter paper, no injury resulted. This he attributed to the capillary action of the filter paper in drawing the copper off the seeds. No injury was noticed when the seeds were grown in soil treated with lime.

Mezentzov (28) in 1902, working in Russia, determined the effects of planting untreated and treated seed in dry and moist soil. The treatments used were copper sulphate with and without subsequent limewater bath, and hot water. He obtained higher germination percentages in moist soil, both with untreated and treated seed.

Henderson (13) in Idaho, in 1906, found that one pound of formaldehyde to 16 gallons of water, sprinkled on oats, did not cause much injury.

Köck (22) found that seed injury from the use of formaldehyde solution varied for the different cereals. Wheat and rye were injured most, oats next, and barley the least. Increasing the strength of the formaldehyde increased the injury. The amount of injury varied with the different varieties of each cereal and with the individual lots of seed.

Sutton and Pridham (41) McAlpine (26) Sutton and Downing (42) Richardson (36) and Hurst (16) working in Australia, found less injury from formaldehyde than from copper sulphate. Liming after treating with copper sulphate lessened the injury. Hurst found that about 25 per cent of wheat was killed by the copper sulphate treatment. McAlpine found that formaldehyde-treated seed showed the lowest germination when the seed had been kept one week. At the end of two weeks the germination was much improved, while four weeks after treating it was as good as it was twenty-four hours after treatment. As a result of this investigation, he concluded that formaldehyde-treated seed should be planted before it dries.

Burmester (5) in 1908, found that copper sulphate injured the germination of wheat most, oats and barley the least.

Stevens (39) in 1909, found that the amount of injury to oats treated with formaldehyde depended upon the duration of treatment, strength of solution and quality of seed. Oats dipped in milk of lime after treatment with formaldehyde showed an improvement in percentage of germination.

In 1910, d'Ippolito (17) in Italy, found that a 5 per cent copper sulphate solution with a duration of treatment for two hours caused injury to oats but that dipping in a 5 per cent milk of lime solution prevented the injurious effects of the copper sulphate solution.

Stewart and Stevens (40) in Utah, found that the injury to wheat, oats, and barley when treated with formaldehyde increased as the concentration of the solution was increased. Wheat was injured most, barley next, and oats least.

Hiltner and Gentner (14) found that copper sulphate caused more injury than formaldehyde.

Lang,[1] in Würtemburg, presents much evidence of the increased injury to wheat treated with copper sulphate when the seed coat had previously been cracked in the process of threshing. He clearly states that his work only emphasizes a fact known for a long time.

Lesage (25) soaked wheat for periods ranging from one hour up to one hundred and ninety-five hours in solutions of copper sulphate up to 40 per cent. Solutions up to 10 per cent caused no injury but did not prevent the growth of moulds on the treated seed. Since most wheat is treated in one or two per cent solutions the author doubts that wheat is injured by treatment.

Müller, Molz, and Morgenthaler (32) noted injury to germination of treated seed. It was more prevalent in Germany during the dry season of 1911.

[1] Lang, W. Die Getreideernte von 1911 und das Beizen. Württemb. Wochenbl. f. Landw. **1912**: no. 13. Sonderabdr.

Brittlebank (4) noted that copper sulphate injured germination more than formaldehyde. He recommends that seed be planted as soon after treatment as possible.

In 1913, Johnson (18) in England, found barley resistant to both copper sulphate and formaldehyde. Wheat was injured most while oats stood strong solutions well. Injury increased as the concentration of the solutions increased. Seeds treated with copper sulphate required twice as much time to germinate.

In 1913, Picchio (34) in Italy, immersed wheat in copper sulphate solutions ranging from .5 per cent to 1.5 per cent for 5 minutes without injuring the germination, but increasing the strength of the solution to 4 per cent in .5 per cent intervals increased injury until it reached 10 per cent. Little injury resulted where wheat was soaked for one hour in a 40 per cent solution of formalin.

Riehm (37) reviews the literature on cereal-diseases in Germany for 1912. During this year Fuschini found that pre-soaking wheat reduced injury from the hot water treatment, formaldehyde and other fungicide treatments. Appel and Riehm found that there was much cracking of seed coats of cereals during the process of threshing during the excessively dry harvest of 1911. In consequence, such seed when treated for smut was severely injured. The observers state that unfortunately this fact is not generally known.

Müller and Molz (30, 31) note that wheat treated with formaldehyde and then dipped in either cold or hot water is not injured very much. They also noted that paraformaldehyde is very injurious to the germination of wheat.

Woolman (45) in 1914, working at the Washington Experiment Station, found much injury to treated wheat due to the cracking of the kernels during threshing.

In 1916, Molz (29) in Saxony, found injury to wheat when treated with formaldehyde. In an artifical seed bed the germination ranged from 14.6 per cent to 96.5 per cent and in field tests from 0 to 85.6 per cent, according to the strength of the solution.

Lakon (24) found that the hot water treatment increased the percentage of germination. If, however, the seeds were planted while wet the percentage of germination was considerably reduced.

Wallden (43) in 1917, noted most cracking of seed coats by threshing machines during dry years. Such seed when treated with formaldehyde or copper sulphate was either killed or germination was greatly retarded. By using a dilute solution of eosin the amount of cracking of the seed coat was determined. It was found that injury from the fungicides increased in proportion to the amount of cracking.

Kiessling (20) found that a 0.1 per cent solution of formaldehyde for 10–20 minutes injured the germination of oats. Fungicidal action was greater and the injury to germination less by moistening the cereals before treating with fungicides. Injury was decreased for wheat by allowing it to stand several days before planting. Paraformaldehyde caused marked injury. Seeds with cracked seed coats were injured most by formaldehyde.

Braun (3) in 1920, found that presoaking of cereals in water decreased the injurious effects of formaldehyde and copper sulphate. By presoaking cereals before treating with fungicides the cell walls of the seeds become saturated with water, thus reducing injury. The presoak method caused a stimulation of germination in a number of cases.

Since the completion of this paper two important papers on seed injury have appeared.[1]

Injury resulting from treating wheat with formaldehyde is attributed to the formation of paraformaldehyde; the injury being greatest in atmosphere with low humidity.

Badly broken seed-coats, especially over the endosperm, are subject to attack by Penicillium and Rhizopus. The vitality of seeds is a factor in determining the ability of saprophytic fungi to attack them. Threshing machine injury is responsible for a large part of the cracking of seed coats.

## AMOUNT OF SEED INJURY

In order to determine the exact amount of injury, samples of wheat were collected from a number of sources in the Pacific Northwest. Most of the samples were obtained from the Office of Grain Standardization, United States Bureau of Markets, Portland, Oregon. Other samples were obtained from county agents of Washington, from the Western Washington Experiment Station at Puyallup, and from the Farm Crops Department of the State College of Washington, Pullman. After all samples of wheat were received, they were divided into groups according to variety. For each test 200 kernels were used, and after treatment the wheat was planted in flats of soil in the greenhouse. The counts for germination were made about ten days after planting.

In the first series of tests, the wheat was steeped for ten minutes in a solution of copper sulphate made at the rate of one pound of fresh copper sulphate to each 5 gallons of water (a 1–5 solution). The seed was then dried over night and planted the next day, and the flat watered at once, unless otherwise stated. In the first set of tests, the variety Red Russian was used. In order to determine how closely the results of duplicate

[1] Hurd, Annie May. Injury to seed wheat resulting from drying after disinfection with formaldehyde. Jour. Agr. Sci. **20**: 209–244. 1920.

——— Seed-coat injury and viability os seeds and barley as factors in susceptibility to molds and fungicides. Jour. Agr. Sci. **21**: 99–122. 1921.

sets would check, four flats were used for each sample. Two flats were planted to treated and two to untreated seed, and the average given in table 1. In the case of the other varieties, only one flat each of treated and untreated seed was germinated. Table 1 gives the results of germination tests after treating with copper sulphate.

After testing all of the different varieties with copper sulphate, from six to twelve samples from each variety that showed the highest seed injury with copper sulphate were dipped for ten minutes in formaldehyde, one pound to 40 gallons of water, two hundred seeds being used for all samples. The results of the treatments with formaldehyde are shown in table 1.

TABLE 1

*Germination of varieties of wheat in per cent following treatment with copper sulphate and formaldehyde*

| VARIETY | TREATMENT | NO. OF TESTS | GERMINATION PERCENTAGE | | | |
|---|---|---|---|---|---|---|
| | | | | | HAND THRESHED | |
| | | | TREATED | UNTREATED | TREATED | UNTREATED |
| Red Russian | $CuSO_4$ | 8 | 59.1 | 91.1 | | |
| " " | Formaldehyde | 8 | 75.2 | 92.6 | | |
| Turkey Red | $CuSO_4$ | 6 | 37.2 | 82.0 | | |
| " " | Formaldehyde | 5 | 82.7 | 91.0 | | |
| Pacific Blue Stem | $CuSO_4$ | 11 | 39.5 | 88.4 | | |
| " " " | Formaldehyde | 6 | 65.3 | 96.1 | | |
| Forty Fold | $CuSO_4$ | 6 | 42.6 | 95.3 | 99.5 | 96.5 |
| " " | Formaldehyde | 6 | 65.3 | 100.0 | | |
| Washington Hybrid 123 | $CuSO_4$ | 13 | 41.2 | 90.5 | | |
| " " 123 | Formaldehyde | 12 | 73.5 | 90.6 | | |
| " " 128 | $CuSO_4$ | 11 | 40.9 | 91.4 | 93.4 | 96.5 |
| " " 128 | Formaldehyde | 10 | 71.2 | 90.3 | | |

## RELATION OF SEED INJURY TO SEED LOT

The results in table 1 show that seed injury from treating wheat with formaldehyde or copper sulphate is general for samples obtained from various portions of the Pacific Northwest. It is also shown that the amount of seed injury is not constant for a given variety but varies with each seed lot. This variation undoubtedly is due in part to the manner in which the wheat has been threshed, since some threshing machines cause more cracking of the seed coat than others. Treatment with fungicides would cause most injury to the wheat that has been cracked the most. The results do not indicate that any one variety is injured more than another. Other factors, such as maturity when harvested, viability of the seed, conditions under which the crop was

raised, influence the amount of seed injury. With the methods used in these experiments the injury from the use of copper sulphate is much greater than when formaldehyde is used.

*Experiments to Determine How to Reduce Seed Injury*

Since it was found that the per cent of injury ranged from nothing to over 80 per cent, methods to offset some of this reduction in germination were tried. In the first series, both presoaking in water and lime treatment were tried. Eight samples of Pacific Blue Stem were used. In treatment one, the ordinary copper sulphate treatment 1–5 (1 pound copper sulphate to 5 gallons of water), for ten minutes, was used. In treatment two, the wheat was first soaked in water for ten minutes, then kept moist for six hours, and finally treated with copper sulphate 1–5, for ten minutes. In treatment three, the operation was the same as for two, except that following the copper sulphate treatment the wheat was given a lime bath (1 pound to 10 gallons water for three minutes), and dried over night before planting. Finally, in treatment four, the presoaking was eliminated and the wheat dipped in copper sulphate 1–5 for ten minutes, and then dipped in lime water. Reference to table 2 will show the beneficial results of combining presoaking with lime. Since this method is not practical on extensive wheat farms, this method of reducing seed injury was not studied by further experiments. Table 2 gives the results.

TABLE 2

*Effects of certain variations in copper sulphate seed treatment on germination of Pacific Blue Stem wheat*

| SAMPLE NO. | GERMINATION IN PER CENT FOLLOWING TREATMENT | | | | |
|---|---|---|---|---|---|
| | CONTROL[1] | NO. 1[1] | NO. 2[1] | NO. 3[1] | NO. 4[1] |
| 1 | 82.0 | 27.5 | 60.0 | 45.7 | 77.5 |
| 2 | 94.5 | 27.5 | 65.0 | 53.0 | 94.0 |
| 3 | 90.5 | 26.5 | 66.0 | 57.5 | 94.5 |
| 4 | 92.5 | 25.5 | 77.0 | 66.6 | 88.5 |
| 5 | 92.0 | 5.0 | 66.0 | 22.5 | 83.5 |
| 6 | 64.0 | 28.0 | 38.0 | 55.5 | 82.0 |
| 7 | 89.5 | 43.0 | 79.0 | | |
| 8 | 94.5 | 45.0 | 92.0 | | |

[1] Control = No treatment
No. 1 = Copper sulphate, 1 lb. to 5 gal. water, 10 min.
No. 2 = Copper sulphate, 1 lb. to 5 gal. water, 10 min.; limed.
No. 3 = Presoaked in water 10 min.; kept moist 6 hours; treated copper sulphate solution 1–5, 10 min.
No. 4 = Presoaked in water 10 min.; kept moist 6 hours; treated copper sulphate solution 10 min.; limed; dried over night.

It will be noticed from the results in table 2 that the difference in favor of liming is very marked for all samples treated. This method of liming is not new and is extensively used in some parts of the world.

Among the farmers of eastern Washington it is commonly contended that it is impossible to kill wheat with copper sulphate solution no matter how strong the treatment or how long the immersion. For that reason, preliminary experiments were conducted using only one seed lot of Pacific Blue Stem wheat, 100 kernels in each test. Different strengths of copper sulphate were used ranging in strength from one pound to five gallons of water to one pound to one gallon of water, and for each solution ten, twenty, and thirty minute periods of immersion. A duplicate series was run in which the copper sulphate treatment was followed by the lime bath. Table 3 gives the results. Note that in all cases there is a reduction of seed injury by liming.

TABLE 3

*Effects of certain variations of copper sulphate seed treatment on germination of Pacific Blue Stem wheat; strength of solution, duration of immersion and liming being varied*

| COPPER SULPHATE SOLUTION | PERCENTAGE OF GERMINATION FOLLOWING IMMERSION | | | | | | |
|---|---|---|---|---|---|---|---|
| | NOT TREATED | 10 MIN. | | 20 MIN. | | 30 MIN. | |
| | | UNLIMED | LIMED | UNLIMED | LIMED | UNLIMED | LIMED |
| Control | 97 | | | | | | |
| $CuSO_4$ 1 lb.-5 gal. | | 78 | 80 | 61 | 84 | 82 | 91 |
| $CuSO_4$ 1 lb.-2 gal. | | 74 | 83 | 61 | 84 | 67 | 83 |
| $CuSO_4$ 1 lb.-1 gal. | | 63 | 81 | 45 | 84 | 25 | 69 |

### *Liming After Treating With Formaldehyde*

While the practice of liming after treating wheat with copper sulphate has been practiced for many years, it was not until the spring of 1918 that similar treatment following the use of formaldehyde was brought to our attention. At that time, treated and untreated samples of wheat were collected from farmers of central Washington for germination, in order to make tests for seed injury. Among the samples sent in was a set treated by County Agent, T. S. Brown of Franklin County, in which one sample had been limed after treatment for ten minutes with a standard 1–40 formaldehyde solution. A very beneficial effect was noted in the limed sample.

In the fall of 1919, and the spring of 1920, field demonstrations were planted in Franklin County by County Agent Brown and the writer. The following four treatments were employed using 100 pounds of wheat

for each lot: (1) copper sulphate 1–5 for ten minutes; (2) copper sulphate 1–5 for ten minutes, then dipped in lime water 1–10 for ten minutes; (3) formaldehyde 1–40 for ten minutes; (4) formaldehyde 1–40 for ten minutes, then dipped in lime water 1–10 for ten minutes. One demonstration was seeded in the fall of 1919 and five in the spring of 1920. Each farmer sowed the specially treated seed at the same rate that he used for his general farm seeding. Samples were sent to Pullman for laboratory germination tests. The results in table 4 show a reduction of injury following the lime bath, after both copper sulphate and form-


FIG. 1. BENEFICIAL EFFECT OF LIME FOLLOWING TREATMENT OF WHEAT WITH FORMALDEHYDE


FIG. 2. BENEFICIAL EFFECT OF LIME FOLLOWING TREATMENT OF WHEAT WITH BLUESTONE

aldehyde treatments. The wheat for laboratory tests was planted in soil in flats, in the greenhouse at Pullman, Washington.

The treatment of wheat in the field was carried out as accurately as possible under field conditions. In order to get more accurate results, some of the untreated samples were treated with solutions carefully prepared in the laboratory. An additional sample was dipped in the lime bath only. Two hundred seeds were used in each 12 x 18 inch flat for the field treated seed, and one hundred seeds in similar flats for the seed treated in the laboratory.

TABLE 4

*Germination of Early Baart wheat following various seed treatments*

| SAMPLE NO. | WHERE TESTED | GERMINATION IN PER CENT AFTER TREATMENT | | | | | |
|---|---|---|---|---|---|---|---|
| | | CONTROL[1] | NO. 1[1] | NO. 2[1] | NO. 3[1] | NO. 4[1] | NO. 5[1] |
| 1 | Field | 55.0 | 49.5 | 63.0 | 55.0 | 69.0 | |
| 1 | Lab. | 79.0 | 19.0 | 58.0 | 63.0 | 90.0 | 88.0 |
| 2 | Field | 93.0 | 57.0 | 78.0 | 48.0 | 95.0 | |
| 2 | Lab. | 91.0 | 11.0 | 57.0 | 69.0 | 96.0 | 96.0 |
| 3 | Field | 78.5 | 38.5 | 72.5 | 12.5 | 68.5 | |
| 3 | Lab. | 85.0 | 58.0 | 70.0 | 70.0 | 83.0 | 87.0 |
| 4 | Field | 99.0 | 90.5 | 94.5 | 86.5 | 94.5 | |
| 4 | Lab. | 97.0 | 61.0 | 75.0 | 93.0 | 96.0 | 100.0 |
| 5 | Field | 81.5 | 57.5 | 71.5 | 48.0 | 76.5 | |
| 5 | Lab. | 81.0 | 39.0 | 68.0 | 70.0 | 95.0 | 92.0 |

[1] Control—Not treated
No. 1—Copper sulphate, 1 lb. to 5 gal., 10 min.
No. 2—Copper sulphate, 1 lb. to 5 gal., 10 min.; limed.
No. 3—Formaldehyde, 1 pt. to 40 gal., 10 min.
No. 4—Formaldehyde, 1 pt. to 40 gal., 10 min.: limed.
No. 5—Limed, 1 to 10, 3 min.

As soon as the plants in the field plots had sent out the second leaves counts were made to determine the stand. Using a yard length in a drill row as a unit, the writer, selecting places at random, made ten counts totaling thirty feet of drill row for each plot. The County Agent, Mr. Brown, made similar counts. These results were tabulated and an average made of the twenty counts. The data in table 5 represent the average number of plants per three feet of drill row. It will be noted that the beneficial effects of liming were more pronounced in the field

TABLE 5

*Field stand of unlimed and limed, treated wheat. Average number plants in three feet of drill row. Average based on twenty counts per plot. Franklin County. Plots on farm No. 2 sown fall, 1919, others spring, 1920*

| FARM NO. | AVE. NO. PLANTS IN 3 FEET OF DRILL | | | | PER CENT IMPROVEMENT FROM LIMING | |
|---|---|---|---|---|---|---|
| | COPPER SULPHATE TREATED SEED | | FORMALDEHYDE TREATED SEED | | COPPER SULPHATE TREATED SEED | FORMALDEHYDE TREATED SEED |
| | UNLIMED | LIMED | UNLIMED | LIMED | | |
| 1 | 13.5 | 17.5 | 16.9 | 34.1 | 29.9 | 42.5 |
| 2 | 6.0 | 9.9 | 7.1 | 10.0 | 65.0 | 42.2 |
| 3 | 15.6 | 26.8 | 18.6 | 26.5 | 71.8 | 42 4 |
| 4 | 21.9 | 33.7 | 22.8 | 31.0 | 53.8 | 35.9 |
| 5 | 12.8 | 21.0 | 14.6 | 22.1 | 64.0 | 51.3 |
| 6 | 16.1 | 29.6 | 19.3 | 29.4 | 83.3 | 52.3 |
| Ave. | 14.3 | 23.1 | 16.5 | 25.5 | 61.3 | 44.4 |

plots than in the greenhouse tests. The plants from the lime-treated seed were more vigorous and had a better developed root system than those from the unlimed seed. This enabled them to better withstand the severe dust and sand storms of this section of the state. Unlimed wheat in plots adjacent to the limed plots were rather badly blown out of the ground.

Farmers continually complain of seed injury after using formaldehyde. In order to test the killing power of formaldehyde, wheat was treated in solutions ranging from one pound to thirty gallons of water to one pound to five gallons of water. The wheat was dipped for ten and thirty minute periods. Table 6 gives the results.

TABLE 6

*Effects of certain variations af formaldehyde seed treatment on germination of Pacific Blue Stem wheat.*

| FORMALDEHYDE SOLUTION | PERCENTAGE OF GERMINATION FOLLOWING TREATMENT | | |
|---|---|---|---|
| | UNTREATED | 10 MIN. | 30 MIN. |
| Control | 95 | | |
| 1 pt. to 30 gal. | | 52 | 77 |
| 1 pt. to 15 gal. | | 54 | 61 |
| 1 pt. to 10 gal. | | 16 | 14 |
| 1 pt. to 5 gal. | | 0 | 0 |

*Relation of Soil Moisture to Formaldehyde Injury*

It is a known fact in the Pacific Northwest that formaldehyde treated wheat planted in a dry soil shows considerable seed injury. In order to procure definite data on this point, two samples of 400 seeds each of treated Turkey Red wheat were planted; one part of each sample was watered at once after planting; the other planted and left two days in dry soil, and then watered. Sample 1 gave 83 per cent germination in moist soil and only 44 per cent in soil watered after 2 days. Sample 2 gave 35 per cent and 29.5 per cent respectively.

Finally experiments were made to determine the effect of liming in reducing seed injury. By using different strengths of solution and different durations of immersion followed by immediate watering in one series and watering only after three days in the other series. The solution marked 1–1, consisted of equal parts of commercial formaldehyde solution and water, while the other solutions were one pint of formaldehyde to ten, twenty, thirty, and forty gallons of water respectively. Nine, 100-seed lots of untreated wheat were used in each series.

TABLE 7

*Germination of Early Baart wheat, not treated and treated different periods with different strengths of formaldehyde solution; planted in moist soil and in dry soil, watered 3 days after planting.*

| STRENGTH OF SOLUTION | SOIL MOIST OR DRY AND WATERED AFTER 3 DAYS | GERMINATION IN PER CENT | | | | |
|---|---|---|---|---|---|---|
| | | NOT TREATED | TREATED 10 MIN. | | TREATED 30 MIN. | |
| | | | LIMED | NOT LIMED | LIMED | NOT LIMED |
| Controls | Soil moist | 73 | | | | |
| | Soil dry | 72 | | | | |
| 1-1 | Soil moist | | 7.5 | 4.5 | 2.0 | 0.0 |
| 1-1 | Soil dry | | 2.0 | 0.0 | 0.0 | 0.0 |
| 1-10 | Soil moist | | 49.0 | 34.5 | 35.0 | 8.0 |
| 1-10 | Soil dry | | 10.0 | 6.5 | 11.0 | 6.0 |
| 1-20 | Soil moist | | 62.5 | 41.0 | 57.0 | 34.0 |
| 1-20 | Soil dry | | 29.5 | 14.0 | 17.0 | 15.0 |
| 1-30 | Soil moist | | 73.5 | 48.5 | 52.0 | 48.0 |
| 1-30 | Soil dry | | 55.0 | 37.5 | 41.0 | 21.0 |
| 1-40 | Soil moist | | 72.5 | 53.0 | 78.0 | 69.0 |
| 1-40 | Soil dry | | 74.0 | 53.0 | 69.0 | 33.0 |

It will be noted that in every case where seed is limed after treatment with formaldehyde that the percentage of germination is increased. The most marked effects in reducing seed injury were obtained with grain treated with the standard strengths of formaldehyde.

## SUMMARY AND CONCLUSIONS

1. Due to the dry atmosphere at the time of harvest in the state of Washington, the wheat kernels are generally dry and brittle at the time of threshing. When such wheat is threshed in machines, with high speed cylinders, the seed coats are badly cracked.

2. Subsequent treatment of this wheat with fungicides causes a high percentage of injury to germination.

3. The injury to seed wheat varies for the different lots of a given variety except that injury is general for samples obtained from various wheat sections of the Pacific Northwest, and varies for the different lots of a given variety.

4. This injury can be overcome by presoaking in water before using a fungicide followed by dipping in lime. This, however, is not practical on a large scale.

5. The most practical method to use in the control of seed injury is to dip the wheat in lime water after treating with copper sulphate or formaldehyde.

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# CONTROL OF STEM GIRDLE OF SPRUCE TRANSPLANTS CAUSED BY EXCESSIVE HEAT

C. F. Korstian and N. J. Fetherolf

With Three Figures in the Text

With the transplanting of approximately a hundred thousand two and three-year old seedlings of Engelmann spruce (*Picea engelmanni*) and Norway spruce (*Picea excelsa*) in 1916 and 1917 at the Cottonwood Nursery, which is located in the Wasatch Mountains 25 miles southeast of Salt Lake City, Utah, at an elevation of 7400 feet, stem girdle became quite serious. Hartley[1] observed and studied this form of injury in this nursery in 1915. He attributed it to heat but stated that further experiments were necessary as no efficient method of control had been discovered.

The seedlings made normal growth and development while in the seed beds, remaining green throughout the winter under the deep snow which covered them for approximately six months. They were shaded during the summer while in the seed beds but the transplant beds were not shaded. From four to five weeks after transplanting, some of the transplants began to turn yellow and ultimately died. Observations were made on two transplant beds which were located side by side, had the same soil conditions, were transplanted at the same time by the same general methods and received the same subsequent treatment. On one of the beds the losses were much heavier than on the other bed, as much as 32.8 per cent greater.

A careful study of the conditions revealed the fact that in the bed showing the heavier loss the trees inclined slightly to the north while in the bed having little or no loss the trees inclined to the south. The difference in the direction of incline was due to the direction in which the transplanting operation proceeded across the beds. In the open trench method which has been commonly used at the Cottonwood Nursery, the soil is removed with a spade, making a V-shaped trench one side of which is nearly vertical. As a matter of fact, however, this so-called vertical side against which the trees are planted has a slight slope in the opposite direction to that in which the transplanting proceeds, or toward that portion of the bed already transplanted.

An examination of the dead trees in the bed in which the transplants leaned slightly to the north showed that a high percentage of them were

[1] Hartley, Carl. Non-parasitic stem lesions on seedlings. Phytopathology **6**: 308–309. 1916.

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affected by stem girdle. Lesions on both dead and living transplants were found most commonly on the south side of the stem extending from about 0.1 inch below the soil surface to 0.3 inch above. However, the greatest injury was noted at the surface of the soil indicating that the lesions apparently began at this point and as they developed extended upward and around the stem. Not until the stem was girdled were lesions found on the north sides of the stems, and in such cases the lesion extended farther up the stem on the south side than on the north.

Working on these premises in the 1918 transplanting, the greater part of the trees were put in the beds with a slight incline to the south, thereby reducing losses to 6 per cent as compared with 22.2 per cent for the previous year. Transplanting in the same manner in 1919 gave a similar reduction in losses. Figure 1 shows two beds with the transplants in-

Fig. 1. Engelmann spruce transplant beds in which the trees incline to the north, showing open stand of 3–1 transplants due to heavy loss by stem girdle.

TABLE 1

*Loss of Engelmann spruce and Norway spruce transplants due to stem girdle during the first growing season on different aspects and with the trees inclined in different directions*

| SPECIES | ASPECT | DIRECTION OF INCLINE OF TREES. | PER CENT LOSS JUNE 2 TO SEPT. 29, 1919 |
|---|---|---|---|
| Engelmann spruce | Level | South | 3.7 |
| " " | " | North | 30.6 |
| " " | " | Vertical | 11.4 |
| " " | South | " | 7.0 |
| " " | North | " | 2.4 |
| Norway spruce | Level | South | 8.5 |
| " " | Level | North | 33.5 |

clined to the north in which loss due to stem girdle was excessive. Figure 2 shows the adjacent beds in which the transplants inclined to the south and in which loss due to stem girdle was very slight.

Pool[2] has shown that surface insolation is greatly affected by aspect

Fig. 2. Engelmann spruce transplant beds adjacent to those shown in Figure 1. The transplants incline to the south, which accounts for the good stand of normal density.

and by the presence of even a sparse vegetative cover. The temperature of the surface of the fine sandy soil in a "blowout" facing the sun in the sandhills of northwestern Nebraska was found to be 145° F., while at the same time the temperature of the soil surface on a northern aspect was 91.5° F. He also found a great difference between the temperature of the soil surface and the temperature a few inches below the surface.

It is well known that although the temperature of the air in the mountains is not unusually high, yet the heat of rocks and gravel exposed to direct insolation at high altitudes is known to be excessive. To further confirm the belief that stem girdle is caused by excessive temperatures of the soil surface and that it can be definitely controlled by transplanting in such a manner that the trees incline slightly to the south, an experiment was initiated in 1919 and repeated in 1920. Lots of 200 trees each of 3–0 Engelmann spruce and Norway spruce were transplanted on June 2, 1919, under varying conditions of aspect and inclination of tree. The results of the experiment are summarized in table 1.

The loss is very much greater where the trees lean slightly to the north than in the beds where the trees were inclined toward the south. As would naturally be expected, a greater loss occurred in the trees planted perpendicularly to the surface of the soil than among those inclined toward the south, but the loss was less than among those having an incline to the north. Trees standing vertically on a southern aspect showed a greater loss than those standing vertically on a northern aspect.

[2] Pool, Raymond J. A study of the vegetation of the sandhills of Nebraska. Minn. Bot. Studies, 4: 185–312. 1914.

Upon several occasions during the summers of 1919 and 1920, temperatures of the upper one-fourth inch of the surface soil were taken simultaneously in the Engelmann spruce transplant beds in which the trees were standing vertically, slightly inclined to the north, and slightly inclined to the south, all being on level ground. Temperatures of the surface soil on July 2 and August 15, 1919, days on which a few clouds were to be seen but on which the sun was shining clearly at the time of observation, and those observed on July 10 and August 16, 1920, two of the warmest clear days of the season, are recorded in table 2.

TABLE 2

*Temperatures of surface soil in Engelmann spruce transplant beds*

| DATE | TIME | TEMPERATURES OF SOIL SURFACE IN DEGREES F. | | |
|---|---|---|---|---|
| | | TREES INCLINED TO SOUTH | TREES VERTICAL | TREES INCLINED TO NORTH |
| July 2, 1919 | 1:10 P.M. | 89.8° | 90.8° | 102.5° |
| " | 1:20 P.M. | 99.5 | 101.8 | 111.0 |
| " | 1:30 P.M. | 101.3 | 104.6 | 111.5 |
| | *Average* | 96.9 | 99.1 | 108.3 |
| Aug. 15, 1919 | 4:00 P. M. | 109.0 | 110.0 | 112.5 |
| " | 4:30 P.M. | 109.0 | 110.5 | 114.0 |
| " | 5:00 P.M. | 108.0 | 110.0 | 111.0 |
| | *Average* | 108.6 | 110.2 | 112.5 |
| July 10, 1920 | 2:45 P.M. | 103.8 | 107.7 | 130.2 |
| " | 2:45 P.M. | 104.0 | 108.9 | 127.4 |
| | *Average* | 103.9 | 108.4 | 128.8 |
| Aug. 16, 1920 | 1:30 P.M. | 110.0 | 119.4 | 123.1 |
| " | 1:30 P.M. | 111.4 | 121.0 | 127.5 |
| | *Average* | 110.7 | 120.2 | 125.3 |

Unfortunately the theremometers available in 1919 were not graduated to read above 114° F., which made it impossible to secure readings on the hottest days of the season. However, the data for 1919 show the relative differences which may be expected under the different conditions. In 1919 a loss from stem girdle of 3.7 per cent occurred when the 3–1 Engelmann spruce transplants inclined slightly to the south, 11.4 per cent when standing vertically, and 30.6 per cent when they leaned to the north. In Norway spruce transplants of the same age there was a loss of 8.5 per

cent when the trees inclined to the south and a loss of 33.5 per cent when leaning to the north, all of which was due to stem girdle. The same aged Engelmann spruce similarly transplanted were used in 1920. The summer of 1920 was more unfavorable for stem girdle than that of 1919, because of greater rainfall, more cloudy weather, and the fact that high temperatures were of shorter duration. In 1920 no loss occurred in the beds with the transplants standing vertically or leaning to the south, while a loss of only 4 per cent occurred in the case of the transplants inclined to the north, of which an additional 4.8 per cent were unhealthy because of stem girdle.

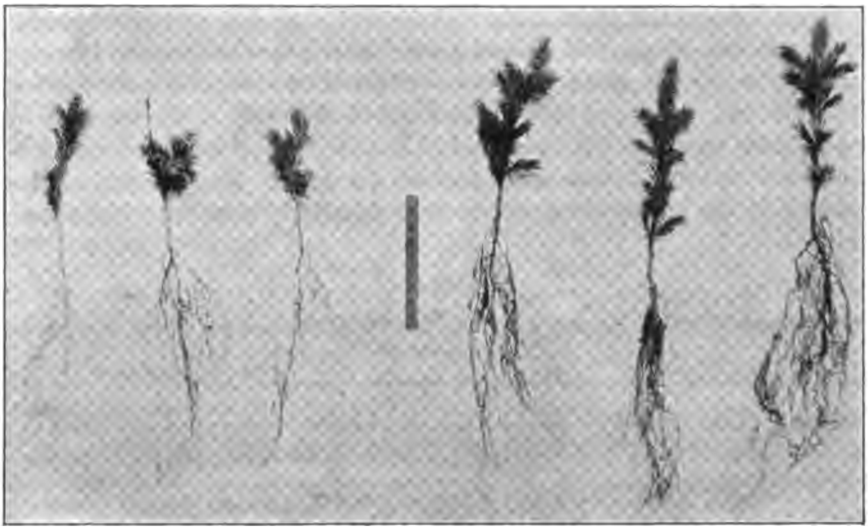

Fig. 3. Typical 3-1 Engelmann spruce transplants grown three years in the seed bed and one year in the transplant bed; those to the left of the rule are affected with stem girdle, while those to the right are healthy. The apparent constrictions due to stem girdle may be seen on the injured transplants.

From table 2 it appears that the variation in temperature at the base of the trees is due to the angle at which the sun's rays strike the tree. The angle of incidence of the sun's rays on trees leaning north is small and on those leaning south is large, which accounts for the varying intensity of insolation; it being high on trees inclining north and low on those which incline to the south. In soils containing a considerable admixture of sand or gravel, as is the case with the Cottonwood Nursery soil, radiation from the small stones and gravel is high. In the case of trees standing vertically the insolation and effect of radiation are not so

great as in the case of those trees inclined to the north, because of the changed angle and the shade which the top gives the lower part of the stem even on the south side. The bases of the trees which are inclined to the south are subjected to much less insolation and radiation from the surface of the soil, on account of the shade which the top and the stem afford not only to the base of the stem but also to the surface soil immediately to the south. The evidence pointing to a heat relationship is further strengthened by the fact that all of the cases of injury arising from stem girdle were in transplants where the soil was exposed to the sun. Stem girdle was not found in dense stands where the bases of the trees were shaded.

Table 3 shows the effect of stem girdle on the growth and development of Engelmann spruce transplants grown three years in the seed bed and one year in the transplant bed; those affected by stem girdle were taken from the bed in which the trees inclined to the north while the healthy transplants were secured from the bed in which they leaned to the south. The data in table 3 and figure 3 show a very decided lowering of the quality of the transplants on the basis of all the various criteria considered.

TABLE 3

*Effect of stem girdle on the growth and development of four-year-old Engelmann spruce transplants*

| CONDITION | AVE. WEIGHT OF TOPS | AVE. WEIGHT OF ROOTS | RATIO OF WEIGHT OF ROOT TO WEIGHT OF TOPS | AVE. LENGTH OF TOPS | AVE. LENGTH OF ROOTS | DIA. OF STEM AT ROOT COLLAR | TERMINAL GROWTH IN 1920 | LENGTH OF 1 YR OLD LEAVES |
|---|---|---|---|---|---|---|---|---|
| | *Grams* | *Grams* | *Per cent* | *Inches* | *Inches* | *Inches* | *Inches* | *Inches* |
| Stem-Girdled | 1.59 | 0.44 | 36.1 | 3.4 | 8.3 | 0.07 | 0.63 | 0.32 |
| Healthy | 3.85 | 1.93 | 45.0 | 5.3 | 10.4 | 0.15 | 1.46 | 0.41 |

From these experiments it is very evident that stem girdle is caused by excessive heat and that it can be eliminated in normal seasons or reduced to a negligible amount in seasons having predominatingly high temperatures. Frequent watering has a slight preventive effect in lowering the temperature of the surface soil, but the results are only of a temporary nature. The control of stem girdle by inclining the trees slightly to the south at the time of transplanting is by far the best and most efficient method of control which has been discovered.

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# NOTE ON THE HYDROGEN-ION CONCENTRATION OF POTATO DEXTROSE AGAR AND A TITRATION CURVE OF THIS MEDIUM WITH LACTIC ACID

E. F. Hopkins[1]

With One Figure in the Text

The widespread use of potato dextrose agar as a culture medium by plant pathologists and the frequent practice of adding lactic acid to it to prevent bacterial contamination in the course of isolation work would make it seem worth while to report a study made, incidental to other investigations, on the reaction of this culture medium. The reaction is expressed as pH according to Sörensen (3). The colorimetric method of Gillespie (1, 2) was used and color and turbidity were compensated by means of a method devised by Walpole (4). The tubes were arranged as follows:

| | |
|---|---|
| Culture Medium | Culture medium + indicator |
| Color Standard | Water |

A comparison block as illustrated by Gillespie (1, 2) was found to be very convenient in making the readings. The indicator was added to the agar while it was still liquid and both this tube and the comparison tube allowed to cool to room temperature before reading. No difficulty was experienced in making comparisons with the standards.

## PREPARATION AND REACTION OF THE MEDIUM

The following formula was used in the preparation of all lots of the potato-dextrose agar:

| | |
|---|---|
| Pared potatoes | 200 gms. |
| Dextrose | 10 gms. |
| Agar | 20 gms. |
| Water (tap) | 1000 cc. |

The potatoes were cut in small cubes and cooked with about three-fourths of the water in a double boiler until "done" but not disintegrated. The potato broth was then filtered through cheese cloth. A good grade of pure granulated dextrose and Difco agar were used. Before the agar was added to the potato broth it was placed in a cheese-cloth sack and washed in running water for about an hour. After the agar and dextrose were added to the potato broth and the whole made

[1] Published by permission of the Director of the Missouri Experiment Station.

up to volume, the medium was steamed in an Arnold sterilizer for one hour to coagulate the precipitate. It was then filtered through absorbent cotton, tubed and sterilized at fifteen pounds pressure for twenty minutes. A good clear medium resulted in all cases.

In one preparation hydrogen-ion determinations were made at various stages to find out what change might be effected by any part of the process, with the following results:

| Steps | pH |
|---|---|
| Potato broth | 6.3 |
| After the addition of dextrose | 6.9 |
| After the addition of agar and steaming for one hour | 7.4 |
| After sterilizing | 6.9 |

The values obtained in testing preparations made by four different workers from five different lots of potatoes are shown in table 1. Sample No. 9, made from new potatoes, shows about the same reaction as the other samples prepared from old ones.

TABLE 1
*The hydrogen-ion concentration of potato agar*

| SAMPLE | pH | | |
|---|---|---|---|
| | BROM THYMOL BLUE | PHENOL RED | AVERAGE |
| 1 | 6.9 | ... | 6.9 |
| 2 | 7.3 | ... | 7.3 |
| 3 | 7.4 | 7.3 | 7.35 |
| 4 | 7.4 | 7.4 | 7.4 |
| 5 | 7.4 | 7.2 | 7.3 |
| 6 | 7.4 | ... | 7.4 |
| 7 | 7.5 | 7.6 | 7.55 |
| 8 | 7.7 | 7.8 | 7.75 |
| 9 | 7.3 | 7.4 | 7.35 |

The above data show that without any adjustment of reaction a medium which is practically neutral is obtained. The average of these nine samples gives the value pH 7.37 ± .05. This accounts for the fact that it is an excellent substratum for many species of bacteria. It is interesting to note that such strenuous treatment as steaming for one hour in the Arnold followed by autoclaving causes only such a small change in the reaction. One might expect the sugar to break down and cause a marked shift in reaction towards the acid side. Slight if any change in color indicated furthermore that the sugar did not break down.

EFFECT OF LACTIC ACID ON THE REACTION OF THE MEDIUM

The change in reaction experienced on adding lactic acid to potato agar besides showing the reason for the inhibition of bacterial growth should show also the amount of buffer action exhibited by this medium.

A solution of lactic acid (50 per cent by volume) was prepared, and a varying number of drops of it added to tubes containing 20 cubic centimeters of potato agar and the pH determined. As a previous experiment had shown that one drop of this strong solution had shifted the pH from 7.0 to 4.5 a solution one-eighth as strong was prepared and used in the same manner. Values were thus obtained between 7.0 and 4.5.

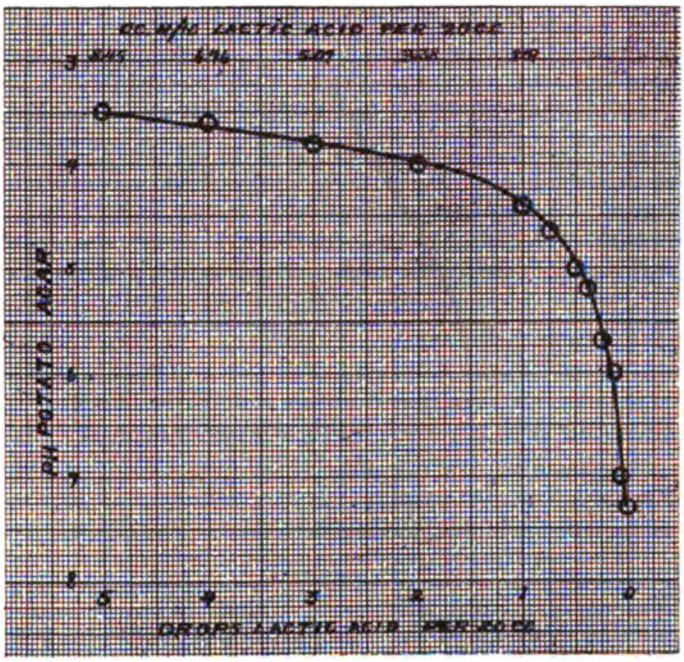

FIG. 1. A titration curve of potato dextrose agar with 50 per cent lactic acid.

Although it is not necessary to know the absolute concentration of the lactic acid as the hydrogen-ion concentration is usually determined later, titrations were made of the lactic acid solution used. The same pipette was used for dropping the acid and was always held vertically. It was found on titrating 1, 2, 4 and 7 drops of the strong solution with N/5 NaOH in the presence of phenolphthalein that the average value of one drop was equivalent to $0.845 \pm 0.004$ cubic centimeters N/5 solution or 0.053 gm. lactic acid per drop. One cubic centimeter of the solution was then titrated and required 35.62 cubic centimeters N/5 solution. This is equivalent to 0.6412 gm. lactic acid or the solution was about 7N. In table 2 the pH values obtained by varying the concentration of the acid are shown.

TABLE 2

*The effect of lactic acid on the reaction of potato agar*

| Drops of 50% lactic acid | 0 | 1/8 | 2/8 | 3/8 | 4/8 | 6/8 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 7.3 | 6.0 | 5.7 | 5.2 | 5.0 | 4.65 | 4.4 | 4.0 | 3.8 | 3.6 | 3.5 |

These data are plotted as a titration curve (Fig. 1). The lactic acid is expressed both as drops of a 50 per cent solution and as cubic centimeters of an N/10 solution, and the acidity as pH. The shape of the curve shows that this culture medium exhibits considerable buffer action and also what values may be obtained. If one drop in 20 cubic centimeters shifts the acidity to pH 4.4 it is then clear why this procedure prevents the growth of certain organisms entirely and allows others to grow. A practical application is of course the common practice of preventing bacterial contamination. It may be suggested that where a fungus is sensitive to acid, a point could possibly be located where bacterial growth would be inhibited but still allow the development of the fungus. Differential isolation of fungi has been accomplished also by varying the acidity.

Another application is in the determination of the effect of hydrogen-ion concentration on the growth and spore production of fungi. Very uniform growth-acidity curves have been obtained by using poured plates of potato dextrose agar of varying acidity and expressing the amount of growth by means of the diameter of the colonies.

## SUMMARY

The hydrogen-ion concentration of potato dextrose agar is easily determined colorimetrically and is quite constant. The average for nine different preparations gives the value pH 7.37 ± .05.

The effect of lactic acid on the reaction of this medium is presented as a titration curve and suggestions as to its application are made.

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# SOME FACTORS AFFECTING THE PRODUCTION OF APOTHECIA OF SCLEROTINIA CINEREA

Walter N. Ezekiel

## INTRODUCTION

When stone fruits are rotted by *Sclerotinia cinerea* (Bon.) Schroeter, the sclerotia of the fungus develop in the fruits. The perfect, apothecial, stage is produced from these sclerotia, after the old mummied fruits have been on the ground for a certain length of time. This much has been known since 1902, when Norton (5) first described the apothecia. Pollock (7) has found that plum mummies ten years old are still capable of producing apothecia. But how soon after the decayed fruits fall to the ground apothecia may be produced, and what conditions favor or retard their development, have been in doubt.

Norton (6) stated that as far as he could judge, the apothecia that he found came only from mummied fruits over one year old. Working with buried plum and apple mummies, Valleau (10) found that no apothecia developed until the second spring. Similar results had been obtained by Aderhold and Ruhland (1, 2) with *S. fructigena* on apples and "*S. laxa*" on apricots. On the other hand, Reade (8), in a taxonomic description of "*S. fructigena*," states; "The fungus has been grown on artificial media from ascospores to ascospores again, and completes its life cycle in one year." Roberts (9) in an experiment performed the same season as the work presented in this paper, found that apothecia could develop in less than one year.

The assumption that burying mummies would prevent the production of apothecia has been the basis of the general recommendation to plow brown-rot mummies under. This was advocated by Dandeno (4), for instance, because some decayed plums he buried did not produce apothecia. Brooks and Fisher (3) observed that most of the apothecia in an orchard which they inspected came from mummies near the surface of the soil.

Experiments were begun in July, 1920, to throw light on some of these points. The specific purposes were to determine: 1, the effect of various conditions on the production of apothecia; and 2, if a dormant period of over a year is necessary before apothecia can be produced. The work was done with Prof. J. B. S. Norton, at the Maryland Experiment Station.

TABLE 1

*Summary of series 1, fruits inoculated with Sclerotinia cinerea July 22, 1920 and distributed as indicated, Aug. 20. (The symbols A, B, C, D, and E, used here, are explained below).*

| LOT NUMBER | NUMBER OF MUMMIES IN LOTS | | PLACED AT | TRANSFERRED TO | DATE OF TRANSFER | APOTHECIA PRODUCED |
|---|---|---|---|---|---|---|
| | PLUMS | PEACHES | | | | |
| 1 | 105 | 30 | C | | | |
| 2 | 60 | 15 | C | D | Dec. 11 | |
| | | | | E | Jan. 31 | |
| 3 | 60 | 15 | C | D | Dec. 11 | |
| 4 | 30 | — | D | E | Sept. 16 | |
| 5 | 60 | 15 | D | C | Oct. 14 | |
| | | | | D | Dec. 9 | |
| | | | | E | Mar. 5 | |
| 6 | 30 | — | D | E | Dec. 8 | Jan. 13, 1921 |
| 7 | 30 | — | D | E | Jan. 31 | |
| 8 | 240 | 30 | D | | | |
| 9 | 30 | 20 | * | | | |
| 10 | 30 | 15 | A | E | Oct. 12 | |
| 11 | 30 | 15 | A | E | Dec. 8 | |
| 12 | 30 | 15 | A | E | Jan. 3 | |
| 13 | 1790 | 755 | A | | | Mar. 14, 1921. |
| 14 | 15 | 5 | B | A | Jan. 3 | |
| 15 | 10 | 5 | B | E | Jan. 3 | |
| 16 | 15 | 5 | B | A | Jan. 31 | |
| 17 | 10 | 5 | B | E | Jan. 31 | |
| 18 | 15 | 5 | B | A | Mar. 5 | |
| 19 | 10 | 5 | B | E | Mar. 5 | |
| 20 | 175 | 70 | B | | | |

* Lot 9 remained on table in laboratory.

EXPLANATION OF SYMBOLS USED IN TABLE 1.

A—Natural conditions. The location chosen was between two greenhouses, where the ground had been in sod for a number of years. Mummies were placed in covered trays (4′ 6″ × 2′ × 6″) of galvanized 1/4″ mesh wire hardware cloth, sunk four inches below the surface of the ground, leaving two inches above ground. They were filled level to the surface of the ground with a mixture of pure white sand and clay subsoil mixed to resemble approximately a Norfolk Sandy Loam. The mummies were divided into five equal parts, placed (1) on the surface of the ground, (2) half covered with soil, (3) entirely covered, (4) buried one inch, and (5) buried two inches, respectively.

B—Mummies suspended in the air in wire-mesh trays, to simulate mummies hanging on trees.

C—Temperature 30° C., in incubator. Mummies kept in water-tight, paraffined boxes, filled with the soil mixture used in A. Soil moisture variations maintained by dividing each lot between three boxes; in one the soil was kept dry, in the second moist, and in the third saturated. Depth variations as in A.

D—Temperature 9° to 11° C., in refrigerator, until November 24, 1920. After this, exposed to natural winter temperatures outside. An unheated shelter protected the

boxes from rain and snow. Soil moisture variations maintained as in C, and depth variations as in A.

E—Temperature, daily range of 10° to 25°, in greenhouse. Mummies transferred here were kept in boxes provided with holes for drainage, and were all kept in moist soil. Depth variations as in A.

## EXPERIMENTAL METHODS

The general method employed was to place peach and plum mummies under different conditions, making observations at least once every five days throughout the duration of the experiment. Three variables were considered; temperature, soil moisture, and depth at which mummies were placed in the soil. Two series of experiments were run, the first with mummies obtained by inoculating fresh fruit, and the second with old peach mummies gathered from the orchard.

*Series 1.* The mummies used in this series were obtained by inoculating sound peaches and plums with brown-rot conidia from local peaches on July 22, 1920. About one bushel of Marianna plums and two bushels of peaches were inoculated and then kept for four weeks on a table in the laboratory at a temperature of 28° to 31° C. On August 20, the mummies were divided into twenty lots and placed under the conditions indicated in table 1.

*Series 2.* On March 11, 1921, large numbers of peach mummies from which apothecia had just started to grow were collected in the University orchards. The small, white, rudimentary apothecia were protruding 3 to 5 millimeters from the mummies. The mummies were kept overnight under a layer of moist soil, and then placed in water-tight boxes well coated with paraffin and filled with a sandy soil. Seventy grams of mummies were placed at each of the following depths in the soil; (1) on surface, (2) half-covered with soil, (3) entirely covered, (4) buried one inch, (5) buried two inches, (6) buried four inches, and (7) buried eight inches. The soil was kept moist, but not saturated; and the boxes placed in the greenhouse at a daily temperature range of 10° to 22° C.

## DEVELOPMENT OF APOTHECIA

On January 13, 1921, three apothecia were found growing from a plum mummy in lot 6, series 1. This mummy was one of those just covered by the soil. No other apothecia developed, in this first series, from any of the many other lots of mummies under artificial conditions. On March 14, 1921, about 25 small apothecia were found starting to develop on the bottoms of mummies under natural conditions (lot 13). By the nineteenth, 43 well-developed apothecia were present; and 78 were counted on March 23. Six days later these had practically all dried up, though on April 5 two apothecia were found.

These apothecia from mummies under natural conditions appeared coincident with the blooming period of stone fruits, which was ab-

normally early this year, the peaches being in full bloom about March 21. This correlation with the blooming period of stone fruits has been frequently mentioned by other writers.

Almost without exception, the apothecia in lot 13 were found growing on peach or plum mummies on the surface of the ground or half covered; only a few developed from mummies just under the surface of the ground. A single apothecium was found growing on a plum mummy buried one inch deep, but none developed from mummies buried deeper than this.

In series 2 (See Table 2) very definite results were obtained as to the depths at which apothecia will develop when sclerotia on which the rudiments of apothecia are visible are buried. Many apothecia

TABLE 2.

*Results of experiment with brown-rot mummies, gathered in orchard March 11, 1921, after apothecia developed sufficiently to protrude from mummies.*

| DATE | NUMBER OF APOTHECIA PRESENT ON MUMMIES | | | | | | |
|---|---|---|---|---|---|---|---|
| | ON SURFACE OF SOIL | HALF-COVERED WITH SOIL | ENTIRELY COVERED | BURIED 1 IN. | BURIED 2 IN. | BURIED 4 IN. | BURIED 8 IN. |
| Mar. 14 | 12 | 32 | 0 | 0 | 0 | 0 | 0 |
| Mar. 16 | 12 | 47 | 0 | 0 | 0 | 0 | 0 |
| Mar. 19 | 15 | 61 | 0 | 0 | 0 | 0 | 0 |
| Mar. 23 | 19 | 55 | 0 | 0 | 0 | 0 | 0 |
| Mar. 26 | 26 | 54 | 0 | 0 | 0 | 0 | 0 |
| Mar. 29 | 3 | 10 | 0 | 0 | 0 | 0 | 0 |
| Apr. 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |

were produced from the mummies on the surface of the ground and from those that were half covered with soil, but none from any of the buried ones.

## CONDITIONS AFFECTING THE PRODUCTION OF APOTHECIA

It is clear from the foregoing that the development of apothecia is inhibited by burying mummies in the soil. With the sandy soil used, the production of apothecia was prevented in all cases by burying mummies two inches deep. This agrees with the general belief that plowing mummies under will prevent the production of apothecia. That this practice will be effective even after the apothecia have started to grow is evident from the results obtained in series 2.

The effect of cold on the production of Sclerotinia apothecia was shown by the development of apothecia in lot 6, series 1. Here apothecia were produced in twenty-five weeks from the date of inoculation. Lot 6 had been chilled at 9°–11° C. for twelve weeks and exposed to outside winter temperature for two weeks, during which time the mean temperature was 5.8° C., and the minimum—2.7° C. It appears, then, that exposure to cold tends to hasten the production of apothecia.

## SUMMARY

The production of apothecia from brown-rot mummies has been studied under different conditions. Under natural conditions apothecia may develop the spring following inoculation. Cold is probably a factor influencing the production of apothecia, as apothecia were produced in twenty-five weeks from chilled mummies. Burying mummies below the surface of the ground inhibits the production of apothecia, even if the development of apothecia has already commenced when the mummies are buried.

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# ANTHRACNOSE OF THE GARDEN PEA.

Fred Reuel Jones and R. E. Vaughan

With Plate XXV and Two Figures in the Text

During a survey of the diseases of peas grown for canning purposes in Wisconsin, a single locality was found in 1912 where great damage had been done by anthracnoose caused by *Colletotrichum pisi* Pat. Although the fungus was isolated at this time and its pathogenicity proven, no published report was made. The disease was not seen again until 1920 when specimens were received from another locality in this state. Since in both instances the fungus caused even greater destruction in the area of its occurrence than is commonly caused by

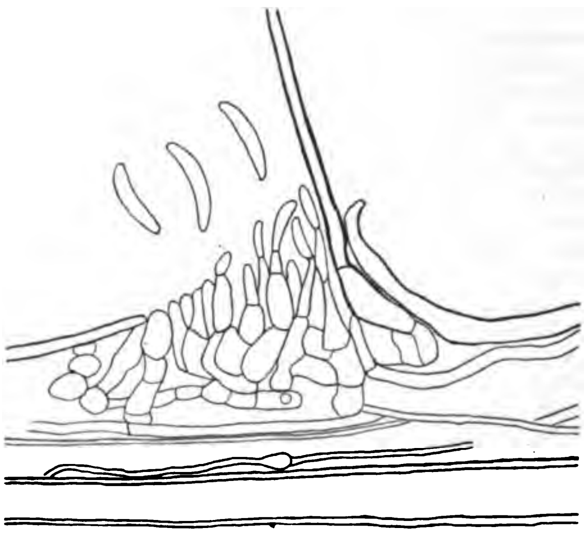


Fig. 1. Colletotrichum pisi Pat. on leaf of garden pea, showing relation of acervulus to the leaf tissue.

any of the well known parasites of peas, it was clear that an extension of its distribution might menace the pea growing industry. Therefore the fungus was again isolated in culture and a study of the disease made.

*Colletotrichum pisi* Pat. was first collected in Ecuador in 1891 by Lagerheim. A comparison of the fungus found in Wisconsin with the description given by Patouillard[1] reveals so many apparent differences

[1] Patouillard, N., and Lagerheim, G. de. Champignons de L'Equator. Bull. Soc. Mycol. France **7**: 158–184 (p. 180). 1891.

that the identity of the fungus was at first in doubt. The chief difference is in spore length, that given by Patouillard being only 11 to 13 microns, while spores from the material in hand range from 15 to 18 microns. However, an examination of a portion of Lagerheim's material in the Pathological Collections of the U. S. Department of Agriculture shows clearly that the measurements given in Patouillard's description are too small, and that there is no essential difference between the fungi (Fig. 1).

The only previous record that has been found of occurrence of this fungus in the United States consists of a collection under this designation on *Lathyrus odoratus* made by W. A. Orton at Macon, Ga., in 1907. The spores found in the acervuli on sweet pea leaves in this collection agree well in measurement with the description of the species to which they are referred, but they do not have the characteristic falcate shape. In view of the fact that infection of sweet peas has not been secured in spite of repeated inoculations, it appears that the fungi on the two hosts are at least physiologically distinct. The only report of the occurrence of this fungus since its description that the writers have found is that made recently by Hemmi[2] in Japan. Here the fungus is said to be widespread, though not often the cause of much damage. A detailed description of the fungus and of the disease is given.

The disease as it appears in the field is well described by Lagerheim as differing little in general character from that caused by the more common fungus, *Ascochyta pisi*. It occurs upon all aerial parts of the plant, and although it has not been detected upon the seed itself, there is no apparent obstacle to the penetration of seeds in diseased pods. Upon leaves, the lesions are irregular in shape, smoky gray or brown toward the margin, and lighter in color, usually tending toward a brown at the center (Pl. XXV). On pods, they are usually lighter in color, more nearly circular in shape, and dark brown at the margin. On stems, the lesions are elongate, rarely encircling the stem, and when covered with spores are ashen when dry and copper color when moist. Setae are sometimes produced so abundantly upon stems that they can be seen with a hand lens. On stems that are nearly mature, the fungus may produce in moist weather rusty areas of considerable extent where spores are produced in tiny acervuli.

The importance of the disease in the United States is, as already stated, probably slight owing to its apparently limited distribution. Unfortunately the localities in which it does occur have not been watched from year to year to determine whether the disease is usually so des-

[2] Hemmi, T. Nachträge zur Kenntnis der Gloeosporien. Jour. Col. Agr. Hokkaido Imp. Univ. **9**: (pt. 6) 309–311, pl. XIII. Aug., 1921.

tructive as during the two years mentioned. That the organism may find suitable conditions for production of destructive epidemics in some of the pea growing districts of the United States is not beyond possibility.

The host range of the fungus studied by inoculation of seedlings in the greenhouse includes, besides horticultural varieties of *Pisum sativum* L., *P. sativum umbellatum* (Mill.), *P. elatius* Bieb. and *P. jomardi* Schrank, through the two latter are not infected as abundantly as *P. sativum.* Attempts to secure infection of varieties of beans and of clover have not succeeded. The spores germinate abundantly on clover leaves, but in no case was the germ tube found to have penetrated the epidermal cell.

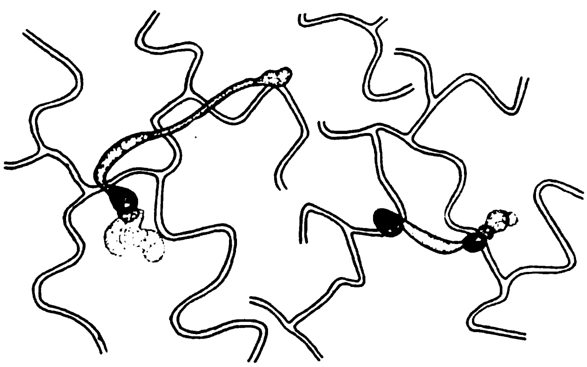
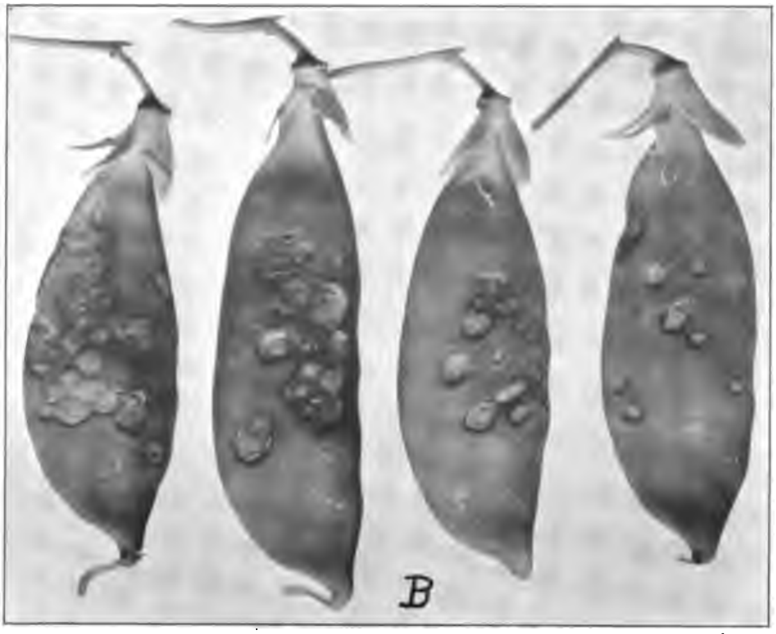


**Fig. 2. Penetration of epidermal cells of a leaf of the garden pea by germinating spores of Colletotrichum pisi, showing appressoria on the leaf surface and mycelium within the cell 36 hours after inoculation at 21° C.**

Cultures of the fungus have been obtained readily from spores which are usually very abundant upon stem lesions. It grows upon all common media, but upon most it does not fruit readily. The surfaces of the substrata become covered with black sclerotial bodies merging to form a crust upon which a few spores are sometimes found. Upon oatmeal agar that has become somewhat dried, a few deep yellow acervuli have been found near the advancing margin of growth. The most satisfactory substrate for spore production yet found is mature woody sweet clover or pea stems. New isolations transferred to these stems produce little aerial growth, while the fungus traverses the surface tissue of the stems upon which it produces in about a week an area of tiny convergent acervuli heaped with spore masses of a golden yellow or salmon color. Setae are produced sparingly. Very soon black sclerotial bodies appear at the point of inoculation, whence they spread


COLLETOTRICHUM PISI ON GARDEN PEAS

FIG. A. Lesions on leaf and stem of the garden pea. Photographed from plants inoculated in the field

FIG. B. Lesions on pods of garden pea. Photographed from plants inoculated in the greenhouse.

and replace the acervuli. Cultures which were kept upon artificial media for a year or even a shorter period of time produced spores less freely than recent isolations.

The conidia germinated readily upon agar plates to which no nutrient material was added at temperatures from 10° to 30° C. in 18 hours, the longer germ tubes being formed at temperatures between 20° and 30° C. In 24 hours spores germinated at temperatures down to 7° C. The method whereby the fungus enters the host is easily observed by decolorizing leaves at intervals after they have been sprayed with a spore suspension. At 21° C. spores germinated and produced appressoria on the leaf surface in 26 hours (Fig. 2). The germ tube produced at one, or often at each end of the spore is usually very short, the appressorium being formed very close to the end of the spore. After germination the spore sometimes appears to have a septum, but no true septum was demonstrated by staining. The appressorium is an irregularly rounded structure, conspicuous by its reddish brown color, and located more commonly near the edge of an epidermal cell. At the end of 36 hours at 21° C. the fungus was found to have penetrated the epidermal cell directly beneath the appressorium and to have begun to produce mycelium which was thick and rounded at first until the cell was partly filled with a stroma-like mass, after which mycelium began to radiate through the surrounding cells.

At present nothing is known regarding the method whereby the fungus survives the winter and becomes transported from place to place. Search will be continued for a possible ascogenous stage which has been suggested by the many small sclerotium-like bodies appearing in culture. It is not unlikely that seeds become infected and carry the fungus from place to place, though this has not been demonstrated.

## SUMMARY

Anthracnose of the garden pea caused by *Colletotrichum pisi* Pat. has been found causing great damage to peas grown for canning purposes in two localities in Wisconsin in 1912 and 1920. At present the disease appears to be of limited distribution in America. The fungus infected readily all species of the genus Pisum that were tried, but no host outside of this genus was found. A brief description of the relation of the fungus to its host is given.

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## BRIEFER ARTICLES

### PHYTOPHTHORA INFESTANS ON EGGPLANT IN THE UNITED STATES

R. J. Haskell

It will be recalled that during the growing season of 1915, conditions in the important late potato sections of the United States were particularly favorable for the development of *Phytophthora infestans*. The result was that late blight of potatoes occurred very widely, not only in the northeastern part of the country but also in the Great Lake States. The outbreak of that year has been recorded as one of the worst epiphytotics in the history of late blight in this country, ranking along with those of 1902–1905 in destructiveness.

During the summer of 1915 the writer was stationed in a field laboratory at East Fishkill, Dutchess County, New York. Among the plants being grown in the experimental garden, which occupied one corner of a thirty-two acre potato field, were six eggplants, all closely surrounded by potato vines. Early in August, Phytophthora began to appear on potato plants in the main field and by the end of that month all vines were badly affected. During the first week in September it was noticed that some of the fruit pedicels and calyces of the eggplants had blighted, and a few of the younger fruits, a number of which were still mere buds, were decaying. The lesions, which were confined mostly to the fleshy pedicels and calyces, were reddish-brown in color, somewhat sunken, and in most cases were covered more or less thickly with a white downy-mildew. When examined under the microscope this fungus appeared to be *Phytophthora infestans* and when microscopically compared with the fungus from potato the two were seen to be identical, at least with respect to the morphological characters. Measurements of the conidia showed them to be 23–35 x 15–23μ (av. 30 x 19μ), and when checked with the sizes of conidia of *P. infestans* from potato as reported by various other workers, it will be seen that they are in close agreement. Some of the measurements given for *P. infestans* are:

| | |
|---|---|
| Schröter (4) | 27–30 x 15–20 μ |
| Rosenbaum (3) | 27.08 ± .145 x 18.27 ± .102 μ |
| Butler (1) | 22–32 x 16–24 μ |
| Massee (2) | 25–30 x 15–20 μ |

As far as the writer is aware, this is the first report of the occurrence of *P. infestans* on the eggplant in this country but in Japan (5) the fungus has been recorded on this host (Kuroishi, Province Mutsu, 1913). In that country two different Phytophthoras occur on *Solanum melongena*, one *P. infestans* (Mont.) De Bary, chiefly on the calyces, and the other, *P. melongenae* K. Sawada, on the fruit (6). The conidia of the latter

organism are considerably larger than those of *P. infestans*, being 24–72 x 20–48μ (av. 42.4 x 33.9μ) so that there is little likelihood of confusing the two species when spore measurements are taken.

It is probable that *Phytophthora infestans* will never become a serious disease of eggplant in this country as this crop is southern in its range and for proper growth demands a climate which is not favorable to the late blight fungus. However, along the northern limits of its culture, and during late blight years, the disease may be expected to appear and possibly prove troublesome in certain restricted localities.

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## WOJNOWICIA GRAMINIS (McALP.) SACC. AND D. SACC. ON WHEAT IN THE UNITED STATES

H. H. McKINNEY AND A. G. JOHNSON

In connection with investigations on take-all and similar diseases of wheat conducted by the Office of Cereal Investigations, United States Department of Agriculture, in cooperation with the various States concerned, the writers visited a number of fields of diseased wheat in Dickinson County, Kansas, in June, 1921, in company with Professor L. E. Melchers, Plant Pathologist of the Kansas Agricultural Experiment Station. Owing to the fact that the disease in question showed the general field and plant symptoms attributed to the true take-all or foot-rot of Australia and Europe, a search was made for the perithecia of *Ophiobolus graminis* Sacc. and other organisms associated with the disease in foreign countries. While perithecia of *O. graminis* were not found, mature pycnidia of another fungus were found rather generally associated with the disease in a number of fields. Microscopic examination showed this fungus to agree in every respect with the descrip-

tion of *Wojnowicia graminis* (McAlp.) Sacc. and D. Sacc. (*Hendersonia graminis* McAlpine). This fungus was first described and illustrated by McAlpine from Australia (Take-all and white-heads in wheat. Jour. Dept. of Agr. Victoria, Australia, **2**: 410–425, 1904). McAlpine strongly suspected this form to be the pycnidial stage of *O. graminis* Sacc., the organism to which he and other workers attribute the cause of take-all or foot-rot. As far as known, *W. graminis* has not been previously reported in America.

Shortly after finding *W. graminis* on the Kansas material, both the pycnidia of this form and perithecia of *O. graminis* were found on dried wheat plants from Arkansas affected with take-all. The latter specimens were collected June 11, 1921, near Fayetteville, Arkansas, in company with Professors J. A. Elliott and H. R. Rosen, Plant Pathologists at the Arkansas Agricultural Experiment Station.

In July, 1921, the mature pycnidia of *W. graminis* were found by one of the writers (McKinney) on wheat plants which had been sent to the Plant Pathological laboratory of the Oregon Agricultural College, from LaGrande, Oregon. These plants showed a distinct mycelial plate and other symptoms attributed to the true take-all or foot-rot disease of wheat.

The pycnidia of *W. graminis* were found on the lower leaf sheaths both above and below the soil line. Usually they were found on the inner side of the sheath, later breaking through the sheath in the same manner as observed in the case of perithecia of *O. graminis*. With the naked eye or hand lens the pycnidia of *W. graminis* are apparently indistinguishable from the perithecia of *O. graminis*.

Preliminary studies have been made on artificial cultures of both forms. Cultures of *O. graminis* were obtained from three sources: 1, From Messrs. R. S. Kirby and H. E. Thomas, Department of Plant Pathology, Cornell University, Ithaca, N. Y., 2, from isolations from material collected near Corvallis, Oregon, by A. G. Johnson and Professors H. P. Barss and M. B. McKay of the Oregon Agricultural Experiment Station, and 3, from isolations made from the above mentioned material collected near Fayetteville, Arkansas. Cultures of *W. graminis* were obtained from spore isolations from the material, referred to above, collected in Kansas and Arkansas.

While it is not the present purpose primarily to consider the genetic connection between these two forms, as naturally this will require further study, it may be stated that the cultural characteristics of the two forms, *W. graminis* and *O. graminis*, on the same culture media, differ distinctly. This makes it seem rather doubtful if they are genetically connected.

INCIDENCE OF LOOSE-SMUT IN WHEAT VARIETIES

F. D. FROMME

During a wheat disease survey in Roanoke county, Virginia, in 1920, it was noted that all fields of the Leap variety (Leap Prolific) were practically free from loose-smut, *Ustilago tritici*.[1]

The amount of loose-smut found in any field of this variety did not exceed a trace, and often such affected heads as were seen were found to be of a bearded variety the seed of which had been mixed with that of the beardless Leap. In sharp contrast it was found that Stoner, a bearded variety which is grown extensively in the State, was generally and quite uniformly infected, the majority of the fields showing about 3 per cent affected heads. Later observations in other counties during the same season revealed the same condition with respect to the occurrence of loose-smut in fields of the two varieties in question, and such previous survey records as were available were also in agreement.

During the season of 1921 especial attention was given to the occurrence of loose-smut in fields of these varieties, and additional data were obtained. In all 52 fields of Leap have been inspected during the two seasons and not one has been found in which the amount of infection has been in excess of a trace. The fields were in 12 counties in practically all sections of the State. During the same seasons and in the same localities 74 fields of Stoner wheat were inspected. In three of these fields the infection did not exceed a trace, but in the remainder it varied from 1 to 10 per cent. These data are summarized in table 1.

TABLE 1

*Incidence of loose-smut in Stoner and Leap varieties of wheat*

| VARIETY WHEAT | NO. FIELDS INSPECTED | PERCENTAGE OF LOOSE-SMUT | | | | | |
|---|---|---|---|---|---|---|---|
| | | O-T | 1-2 | 3-4 | 5-6 | 7-8 | 9-10 |
| Stoner | 74 | 3 | 34 | 18 | 13 | 4 | 2 |
| Leap | 52 | 52 | .. | .. | .. | .. | .. |

* figures show number of fields found with the percentages as indicated.

The writer has shown previously[2] in a summary of the cereal disease survey data from several States that the percentage of loose-smut in fields of Leap in 1919 averaged 0.1 per cent while fields of Stoner averaged

[1] The first observations were made by R. C. Thomas of the department of Plant Pathology of the Virginia Polytechnic Institute and Nelson B. Rue of the Roanoke Chamber of Commerce.

[2] Plant Disease Bull. Suppl. 16: 121. 1921.

3.6 per cent. It is impossible to state without experimental data whether the freedom from loose-smut shown in the Leap variety is a matter of resistance to infection or of disease escape. It is evident that the variety has been abundantly exposed to infection since it has been grown in the State for a number of years and the seed used is chiefly home grown. The mode of infection in loose-smut would suggest that a difference in the exposure of the stigma in the two varieties during blooming might readily account for differences in degree of infection. In a discussion of disease resistance in plants Appel[3] has stated that immunity to loose-smut in wheat and barley is due to the closed flowers found in the resistant varieties. To quote:—"As is generally known, there are wheat varieties which have closed flowers, which means that fertilization takes place within the glumes. In such cases the smut spores cannot reach the stigmas at the proper time, and therefore infection cannot take place." This is evidently a misstatement with respect to wheat, none of the varieties of which have closed flowers according to information available to the writer, but is no doubt true of barley in certain types of which (six-rowed, peacock, and two-rowed erect) the flowers do not open,[4] and the possibility of infection by wind-blown spores would seem to be excluded. That resistance in varieties of this type is a matter of disease escape has been demonstrated by Brefeld[5] who obtained abundant loose-smut infection in a cleistogamous variety of barley, in which the disease had never been observed, by the introduction of spores into the artificially opened blossoms.

The writer has made only a cursory comparison of the blooming of the two varieties of wheat under discussion and has not found any differences that appear to be significant; both have been seen to open during pollination. It is quite possible, however, that a thorough study of this point may reveal a difference in the duration of the exposure or some other feature in connection with blooming which will provide a mechanical basis for the relative immunity of the Leap variety.

It has occurred to the writer that comparative freedom from loose-smut may be associated with the beardless habit, and such data as is available indicates that bearded varieties are more susceptible as a group than the beardless varieties. Table 2 shows occurrence of loose-smut in varietal tests at Blacksburg in 1921, the varieties being grouped in the table according to presence of beard. Most of these varieties have been grown

[3] Appel, Otto. Disease resistance in plants. Science n. s. 41: 778. 1915.

[4] Robbins, W. W. The botany of crop plants, p. 139. 1917.

[5] Brefeld, O. Investigations in the general field of mycology. English translation by Frances Dorrance, part 13, p. 29. 1912.

in close association for a number of years and the exposure to infection should be about the same. It will be noted that the amount of loose-smut shown by the bearded varieties is as a rule considerably in excess of that shown by the beardless ones, and that with the exception of a few

TABLE 2

*Incidence of loose-smut in bearded and beardless varieties of wheat in varietal test plots at Blacksburg, Va., June 3, 1921. Figures are number of affected heads in two 66-foot rows*

| BEARDED VARIETIES | | BEARDLESS VARIETIES. | |
|---|---|---|---|
| Hopper | 36 | Rice | 18 |
| Stoner | 28 | Blue Straw Fultz | 17 |
| Bearded Purple Straw | 25 | Purple Straw | 9 |
| Red Wonder | 22 | Perfection | 6 |
| Lancaster | 21 | Currell Prolific | 6 |
| Mediterranean | 15 | Red Wave | 4 |
| Dietz Amber | 13 | Jones St. Louis Prize | 3 |
| Turkey Red | 13 | Early Ripe | 3 |
| Diamond | 12 | China | 3 |
| Ironclad | 12 | Rural New Yorker No. 6 | 2 |
| Nigger | 11 | Jones Climax | 1 |
| Egyptian | 10 | Red May | 1 |
| Rudy | 10 | Gold Coin | 0 |
| Fulcaster | 8 | Harvest King | 0 |
| Red Rock | 7 | Fultz | 0 |
| Blue Ridge | 5 | Leap | 0 |
| Auburn | 4 | | |
| Davidson | 1 | | |
| Kanred | 1 | | |
| Golden Wave | 0 | | |

TABLE 3

*Percentage of loose-smut in varietal test plots at three sub-stations. The counts at Appomattox by H. L. Lewis in 1918, at Staunton by G. M. Reed and F. D. Fromme in 1920, and those at Chatham by D. J. Burger in 1921*

| VARIETY | TYPE | APPOMATTOX | STAUNTON | CHATHAM |
|---|---|---|---|---|
| Stoner | bearded | 3 | 4 | 5 |
| Red Wonder | do. | 2 | 4 | 4 |
| Fulcaster | do. | 2 | 3 | 4 |
| Harvest King | beardless | 0 | t | .. |
| Fultz | do. | 0 | t | 0 |
| Leap | do. | 0 | t | 0 |

varieties the beardless group is but slightly affected. The average amount of loose-smut in the bearded group is about three times that found in the beardless group, 12.7 against 4.6 per row affected heads. Table 3 shows percentages of loose smut in certain varieties in varietal test plots at three of the sub-stations of the Virginia Agricultural Ex-

periment Station. The data which are for three separate years are in close agreement, the three bearded varieties, Stoner, Red Wonder and Fulcaster, showing quite uniform infection greatly in excess of that shown by the three beardless varieties, Harvest King, Fultz and Leap, which are almost entirely smut-free.

It seems evident that wheat varieties exhibit differences in susceptibility to loose-smut and it appears that control of the disease may be realized by choice of varieties, and possibly also through breeding or selection. Although questions of greater importance enter into the choice of wheat varieties, susceptibility to loose-smut may well be considered in connection with varietal improvement studies, especially in the South Atlantic States.

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## CONVENIENT CHAMBERS FOR INOCULATION OF PLANTS WHERE HIGH HUMIDITY AND MODERATE TEMPERATURES ARE REQUIRED

A. F. CAMP

In making artificial inoculations during a recent investigation of citrus blast[1] at Berkeley, California, it was found necessary to simulate, as far as possible, the winter conditions in the upper Sacramento Valley, where the disease is endemic. Citrus blast appears in this locality only during the rainy periods of January and February and is consequently accompanied by a fairly low temperature and very high humidity amounting at times to almost continual light or misty rain for considerable periods. Cages similar to those described by N. Rex Hunt[2] but about three feet tall, were first built, it being necessary to have them large enough to cover a small orange tree. These cages, however, were too high to be operated by this method. The cloth was saturated for only a short distance before the level in the pans became so low that the water would not rise over the rim fast enough to replace the water evaporated, and the cloth would consequently gradually dry out. This could be partially remedied by keeping the pans on top of the cages constantly at the point of overflowing, by means of a small stream of water. This design was subject to two serious difficulties, 1, the pan on top of the cage must be perfectly level, 2, the stream of water must be accurately adjusted or a ball float used. It was fairly satisfactory, however, in that it provided a very cool atmosphere almost saturated with water vapor due to the evaporation from the cloth.

[1] Fawcett, H. S., Horne, W. T., and Camp, A. F. Citrus blast and black pit. The California Citrograph, 6: 234. May, 1921.

[2] Hunt, N. Rex. The "iceless refrigerator" as an inoculation chamber. Phytopath. 9: 211–212. 1919.

This type of chamber did not prove entirely satisfactory for work with citrus blast because there was insufficient moisture actually present on the leaves. In order to meet this difficulty another form of cage was devised. One large and one small one, to be used as space demanded, were built. In these, Vermorel nozzles, manufactured by the Bean Spray Company, were used to produce a spray or mist. The large apparatus was ten feet high with a floor space 11 x 6 ft. and covered with heavy muslin, the floor was tightly boarded and covered with a heavy roofing paper well cemented and sloped slightly to one corner where there was a drain, and was provided with sides two or three inches high to keep the water from running off the edges. In putting in the flooring the roofing paper was cut and laid without cementing for some time, to prevent its wrinkling on service. To prevent breaking where the roofing paper was cupped up at the sides, it was supported by a two by four ripped diagonally and laid with the long side down.

TABLE 1.

*Temperatures (F.) in the moisture cage at Berkeley.*

| DATE | IN CAGE | | OUTSIDE | | WEATHER |
|---|---|---|---|---|---|
| | MAXIMUM | MINIMUM | MAXIMUM | MINIMUM | REMARKS |
| 10/8 | 62 | 52 | 68 | 48 | |
| 10/9 | 60 | 54 | 67 | 52 | Rainy |
| 10/10 | 61 | 56 | 61 | 53 | Cloudy |
| 10/11 | 62 | 56 | 70 | 52 | Light clouds |
| 10/12 | 62 | 56 | 66 | 51 | Sunshine |
| 10/13 | 62 | 50 | *84 | 46 | Sunny |
| 10/14 | 60 | 52 | *86 | 48 | Sunny |
| 10/15 | 64 | 52 | *84 | 52 | Sunny |
| 10/16 | 62 | 52 | 64 | 46 | Sunny |
| 10/17 | 58 | 53 | 59 | 51 | Cloudy |
| 10/18 | 58 | 54 | 59 | 51 | Cloudy |
| 10/19 | 57.5 | 52 | 58 | 46 | Sunny |
| 10/20 | 58 | 50 | 58 | 42 | Sunny |
| 10/21 | 59 | 51 | 62 | 44 | Light clouds |
| 10/22 | 58 | 53 | 58 | 48 | Foggy |
| 10/23 | 60 | 53 | 62 | 49 | Sunny |
| 10/24 | 62 | 54 | 72 | 53 | Sunny |
| 10/25 | 62 | 54 | 69 | 50 | Sunny |
| 10/26 | 62 | 52 | 66 | 46 | Sunny |
| 10/27 | 61 | 54 | 62 | 50 | Cloudy |
| 10/28 | 61 | 55 | 59 | 50 | Cloudy |
| 10/29 | 64 | 53 | 63 | 49 | Sunny, water off part time |
| 10/30 | 61 | 50 | 66 | 54 | Sunny |
| 11/1 | 55 | 50 | 60 | 42 | Sunny |

* Too high, sun on instrument.

The muslin was put on with considerable slack to make up for the shrinkage and was lapped generously. The muslin was boiled before use so that it would take water freely. In order to keep the cloth on the top quite taut and to avoid an annoying drip, one side was made about a foot higher than the other. A pipe line was carried in about three and one-half feet above the floor and a two hole Vermorel nozzle attached to the end with an elbow so as to shoot upward.

With this apparatus and with sufficient pressure on the pipe line, a very fine mist was obtained which did not tend to wash the foliage sufficiently to carry away the inoculum. The pressure used at Berkeley was probably not in excess of fifteen pounds, but with more pressure a finer mist would result. The sides and roof wet by the spray kept the temperature well down, as shown in the accompanying table. The height from the floor to the roof was found to be necessary to avoid dripping and to make the spray fine enough.

Where an absence of drip due to the spray actually coming in contact with the leaves is desirable, it was found feasible to hang a frame work or roof about six feet by three feet under the nozzles, leaving a space between it and the wall all the way around. The plants when placed under this roof were in a saturated atmosphere and yet were not wet directly by the spray. This roof may be covered with roofing paper or with a fabric similar to oiled silk so that the light may pass through. For individual covers for plants large panes of glass answered very well.

In order to work where space was restricted, a small cage was made to set in a four foot square metal pan. The cage was about three and one-half feet high with a single Vermorel nozzle pointing downward thru the top. About six inches below the nozzle a glass plate about six inches square was suspended. The cone of water from the nozzle which had a very small opening, struck this plate and was thoroughly broken up. The sides were kept wet easily and the only annoyance was the drip from the glass plate. For a few small plants it is easy to substitute a pane of window glass for the small glass plate, the plants being placed under this shelter which is tilted just enough to prevent any drip on the under side.

## PHYTOPATHOLOGICAL NOTES

*Phoma insidiosa on sorghum.* In the paper "Phoma on Sweet Sorghum,"[1] the writers tentatively gave the fungus the name *Phoma insidiosa* F. Tassi, until a type specimen of the African fungus could be examined. Through the courtesy of the International Institute of Agriculture in Rome and Dr. F. Tassi of the University of Siena, four of the type specimens of durra sorghum seed have been received. In spite of its age the seed was in perfect preservation and the pycnidium selected for microscopic examination contained abundant conidia. The fungus growing on the Abyssinian seed is similar in appearance, size of pycnidia and conidia, to that found on the sweet sorghum seed raised in Arkansas and is believed to be the same organism. Some of the conidia were measured with the apparatus used in measuring the American specimens. The mean of these measurements of Dr. Tassi's specimen, 6.6 x 3.6µ, is larger than his published measurement, which is 6 x 2–2½µ, but it corresponds to those of the conidia taken from the seed coat of the sweet sorghum, Planters' Friend. This difference in measurements can easily be attributed to the difference in methods of measuring. Dr. Tassi described the fungus as producing ash colored or white spots on the epidermis of the seeds. It happened that the American sweet sorghum seed which was examined did not show these spots. However, it was found that the spots could be produced when the fungus was cultivated on sorghum seedlings in the laboratory. If the atmosphere was very humid, a group of rapidly growing pycnidia would raise and rip off the upper epidermis for some distance before breaking through it. After this loosened skin dried it assumed an ashy or silvery hue. On one of Dr. Tassi's seed, pycnidia were found protruding without having produced a discolored spot on the epidermis.

The records of the Federal Horticultural Board showed that in 1908, some sorghum seed was imported from Vereeniging, Transvaal, South Africa, which was infested with *P. insidiosa.* In 1914, out of 18 varieties of sorghum imported from Nyembe, Bulungwa, East Africa, 13 varieties had Phoma infected seed.

As *Phoma insidiosa* appeared to infect sweet and grain sorghum equally readily, an attempt was made to find the general geographic distribution of the fungus. Through the courtesy of Dr. H. Vinal of the Office of Forage Crop Investigations, his collection of foreign sor-

[1] Koch, Elizabeth, and Caroline Rumbold. Phoma on Sweet Sorghum. Phytopath. **11**: 253-268. 1921.

ghum seed was examined. The list of the varieties of seed found infected with Phoma shows that the fungus is rather wide-spread throughout the sorghum growing countries. The names of the varieties of sorghum are given when they are known, but as the African varieties did not have definite names they are indicated by the number given them by the Forage Office so that an idea can be obtained of the number of varieties which had infected seed as well as the district in which they grew.

CHINA.

White kai liang. Honan.

INDIA.

Pyaung-shwe-wa. Burmese dry zone. Meiktile.
Dodania. Cawnpore, United Provinces.
Andhri. Cawnpore, United Provinces.
Patcha Jonna. Bellary. Madras.
Palpu Jonna. Madras.
Peria Manjal Cholani. Madras.
Nilwa. Poona, Deccan.
Hundi. Poona, Deccan.
Dukuri. Poona, Deccan.

AFRICA.

No. 1463. Rejaf, Mongalla Province, Ango-Egyptian Sudan.
No. 1467a. Rejaf, Mongalla Province.
No. 1331. Rejaf, Mongalla Province.
No. 1324. Rejaf, Mongalla Province.
No. 1266. Misindi, Northern Province, Uganda.
No. 1301. Panymur, Northern Province, Uganda.
No. 935. Zanzibar, Zanzibar.
No. 916. Kizoma, Zanzibar.
No. 653. Ujiji, Zanzibar.
No. 243. Bulawayo, Victoria Falls, Rhodesia.
No. 130. Basuto land, Pretoria, Transvaal.
Kafir corn, Johannesburg, Transvaal.
No. 115. Taungs, Transvaal.
Kafir corn of the district Vereeniging, Transvaal.

DUTCH WEST INDIES.

Maiz chikitoe hasen harina. Curacao.
Mais chiquito. Willemstad, Curacao.

Dr. Tassi's type specimens, the collection of infested foreign sorghum seed and some of the American seed have been deposited in the herbarium of the Office of Pathological Collections, Bureau of Plant Industry.—CAROLINE RUMBOLD AND ELIZABETH KOCH TISDALE.

*Head smut of corn in Washington.* An inspection was made of sixty different corn fields located in central and southern Whitman County, Washington, during the months of August and September 1921 in an effort to determine the prevalence of head smut of corn (*Sphacelotheca reiliana* (Kühn) Clinton). The disease was found for the first time in this state in two corn fields near Pullman in 1919, and was later reported in popular bulletin 119 of the Washington Agricultural Experiment Station. Inspections were begun in the field where the disease was first discovered. The owner of that farm informed the writer that his 1920 crop of corn was so badly diseased that he had given up the idea of growing corn and had planted his fields to alfalfa. Six different fields quite widely separated from each other, showed limited quantities of head smut in three and an abundance in three others. In one field the head smut was found affecting both *Zea mays indentata* and *Z. mays saccharata.* During the present season (1921) this corn smut has also been reported from the Yakima Valley and found to be quite serious on corn in that section. The disease is not known to occur on sorghum in Washington. Sorghum, however, is not extensively grown in the sections where head smut is found.—CHAS. S. PARKER.

*"Black point" of wheat.*—Observations during the past year have shown that a comparatively high percentage of the kernels of the durum wheats of the Upper Mississippi Valley are often partly or entirely discolored, especially at the embryo end. These areas are dark brown or creosote colored. Hundreds of isolations made from typically discolored kernels have given, in the majority of cases, a species of Helminthosporium similar to *Helminthosporium sativum* P. K. and B. For example, in one series of black pointed seeds (260 kernels of D5 and Acme) 77.6 per cent. of the kernels yielded this fungus, while platings from several series of apparently healthy, plump seed from the same samples gave none of this organism. Likewise, the bran layer from discolored areas, when plated, gave from 85 to 100 per cent Helminthosporium. Discolored seeds when placed in moist chambers gave uniformly a surface sporulation of this same organism. In July 1921, a number of inoculations were made in the field at Madison, Wis. Water suspensions of conidia of the fungus were applied to the heads of Acme and D5 wheat when in flower. Heads thus inoculated were covered with glassine bags for one and two days. In the cases where the inoculations were made when the conditions for infection were most favorable, abundant "black pointed" kernels resulted, in contrast to a low percentage in the controls where only water was applied.—NEVADA S. EVANS.

*Phytopathological Society in the Philippines.*— At a meeting held at the Bureau of Science, Manila, on August 6, 1921, the plant pathologists and other botanists interested organized the Philippine Phytopathological Society Twenty-two persons indicated their interest in the organization and they constitute the charter members of the society. The purpose of the organization is stated in the preliminary announcement of the society:

"It seems desirable for a number of reasons to have a rather informal organization of plant pathologists in the Philippines. The most cogent reason for the information of such a society is to avoid, as much as possible, duplication of effort; although such duplication sometimes has its advantages, in a field where so much new work is urgent as in this country, any two men doing the same work is an extravagance at the present time.

"It is far from the intention that this society shall draw rigid lines of demarcation for the work of each investigator; yet before such a society each individual may talk over his work and outline for future work, and a proper spirit of understanding and cooperation by his associates will cause them to aid the individual in his problems. Such a society will be moreover an aid to good fellowship and a stimulus to research."

The following officers were elected: President, Dean Chas. F. Baker; Vice-President, Colin G. Welles; Secretary, H. Atherton Lee; Treasurer, Gonzalo Merino. A committee was appointed to draw up a constitution and it was agreed that meetings are to be held bimonthly. The matter of applying for affiliation with the American Phytopathological Society is under consideration.—H. ATHERTON LEE AND COLIN G. WELLES.

*Personal.* Mr. W. K. Makemson, formerly Food Products Inspector at Cleveland Office of the Bureau of Markets, has accepted the position of Extension Entomologist and Plant Pathologist in the Florida College of Agriculture.

Mr. J. H. Muncie, formerly Assistant in Plant Pathology at the Michigan Agricultural Experiment Station and more recently Assistant Professor of Plant Pathology at Pennsylvania State College, has accepted an appointment as Assistant Plant Pathologist of the Iowa Agricultural Experiment Station.

Dr. H. W. Dye has resigned as Ass't Professor of Plant Pathology at Cornell University to accept a position as Pathologist in the Research and Development Department of the Dosch Chemical Company, Inc., Louisville, Kentucky.

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